Oslo Sports Trauma
RESEARCH CENTER

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Injury surveillance and prevention in male professional football

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List of Papers

This dissertation is based on the following original research papers, which are referred to in the text by their Roman numerals:

I. Bjørneboe, J., Flørenes, T. W., Bahr, R., Andersen, T. E. Injury surveillance in male professional football; is medical staff reporting complete and accurate? Scand.J.Med.Sci.Sports. 2011. 21**,** 713-720.

II. Bjørneboe,J., Bahr,R., and Andersen,T.E. Gradual increase in risk of match injury in Norwegian male professional football - a six-year prospective study. Scand. J. Med. Sci. Sports. 2012. [Epub ahead of print]

III. Bjørneboe, J., Bahr, R., Andersen, T. E. Risk of injury on third-generation artificial turf in Norwegian professional football. Br.J.Sports Med. 2010. 44**,** 794-798.

IV. Bjørneboe, J., Bahr, R., Andersen, T. E. Video analysis of situations with a high-risk for injury in Norwegian male professional football; a comparison between 2000 and 2010. Br.J.Sports Med. 2013a. [Epub ahead of print]

V. Bjørneboe, J., Bahr, R., Dvorak, J., Andersen, T. E. Lower incidence of arm-to-head contact incidents with stricter interpretation of the Laws of the Game in Norwegian male professional football. Br.J.Sports Med. 2013b. 47**,** 508-514.

Abbreviations

ACL	Anterior Cruciate Ligament
AT	Artificial Turf
CI	Confidence Interval
CISIR	Canadian Intercollegiate Sports Injury Registry
GEE	Generalized Estimating Equations
EC	European Championship
FA	Football Association
FIFA	Fédération Internationale de Football Association
F-MARC	FIFA Medical Assessment and Research Center
MCL	Medial Collateral Ligament
MRI	Magnetic Resonance Imaging
NCAA	National Collegiate Athletic Association
NG	Natural Grass
NH	Nordic Hamstrings
OA	Osteoarthritis
OSTRC	Oslo Sports Trauma Research Center
RCT	Randomized Controlled Trial
RR	Rate Ratio
WC	World Cup

Summary

Football is one of the most popular sports both in Norway and worldwide. Studies have shown that the injury incidence in football matches is approximately 1000 times higher than industrial occupations such as construction and mining.

The overall aim of this thesis was to reduce the risk of injuries in Norwegian male professional football, and the studies are based on a prospective injury surveillance system established in 2000 in the Norwegian male professional league by the Oslo Sports Trauma Research Center (OSTRC). The aim of Paper I was to assess the accuracy of the routine injury surveillance system as performed by medical staff. We compared two different injury recording methods (medical staff registration vs. player interviews) from July through October 2007. In Paper II we monitored the risk of injury in Norwegian professional football, and reported on the injury incidence and injury pattern from 2002 through 2007. In Paper III, we evaluated the risk of injury on artificial turf compared to natural grass from 2004 through 2007. In Papers IV and V, we conducted a video analysis of situations with a high propensity for injury. An incident was recorded if the match was interrupted by the referee, and the player lay down on the pitch for more than 15 s, and appeared to be in pain or received medical treatment. In Paper IV, we compared the incidence of incidents during the 2000 season to the 2010 season. Subsequently, in Paper V, we assessed whether a stricter interpretation of the Laws of the Game, with red cards for high elbows in heading duels and for late/two-foot tackles, could reduce the potential for injuries. A pre-/post-intervention design was utilized, where the rate of incidents and injuries from the 2010 season (pre) was compared to the 2011 season (post).

In the validation of the injury surveillance system, we found that 51% of all injuries were reported by both methods, 30% by medical staff registration only and 19% by player interviews only. For injuries captured by both recording methods, the agreement was very good for the categories body part injured, activity when injured and injury type, and good for severity (Paper I).

During the six-season observation period (Paper III) the incidence of acute injuries was 15.9/1000 player-match hours (95% confidence interval (CI): 14.9-16.8), 1.9/1000 player-training hours (95% CI: 1.7-2.0) and 1.4 (95% CI: 1.3-1.5) overuse injuries/1000 player hours of activity. A linear regression model showed an increase of 1.06 acute match injuries/1000 player-match hours (95% CI: 0.40-1.73) per year, corresponding to a total increase of 49% during the six-year study period. When accounting for interteam variation and clustering effects using a Generalized Estimating Equations (GEE) model, the increase in injury incidence was attenuated (0.92

injuries/1000 player-match hours 95% CI: -0.11-1.95, p=0.083). We did not detect any change in the incidence of overuse injuries (p=0.73), nor in acute training injuries (p=0.49) during the six-year study period.

In Paper III we did not detect any difference in the injury incidence during matches (rate ratio (RR): 1.04, 95% CI: 0.86 to 1.25) or training (RR: 1.07, 95% CI: 0.87 to 1.32) between artificial turf and natural grass, nor in injury location, type or severity between turf types.

In Paper IV we found a rate of incidents of 74.4/1000 player-match hours (95% CI: 67.3 to 81.5) in the 2000 season and 109.6 (95% CI: 102.3 to 116.9) in the 2010 season, an increase from 2000 to 2010 (RR: 1.47, 95% CI: 1.31 to 1.66). We observed a significantly higher rate of opponent-to-player contact and non-contact incidents in the 2010 season. We found no change in the awarding of yellow or red cards between the two seasons.

Paper V showed that the rate of contact incidents was 92.7 (95% CI: 86.0 to 99.4) in the 2010 season and 86.6 (95% CI: 80.3 to 99.4) in the 2011 season, with no difference between the two seasons. We found, however, a reduction in the incidence of head incidents (RR): 0.81, 95% CI: 0.67 to 0.99), and head incidents caused by arm-to-head contact (RR: 0.72, 95% CI: 0.54 to 0.97). We found no difference in tackling characteristics or injury rate caused by player-to-player contact.

Conclusions

Prospective injury surveillance by team medical staff in Norwegian male professional football underestimates the incidence of time-loss injuries by at least one-fifth. The six-season injury registration documented that the overall incidence of acute match injuries in Norwegian male professional football increased by 6 % per year during the study period, although this increase was not consistent across teams. No significant differences were detected in injury rate or pattern between third-generation artificial turf and natural grass in Norwegian male professional football. We found an increased rate of non-contact and opponent-to-player contact incidents in both heading and tackling duels with a high injury potential in the 2010 season compared to ten years earlier, even if there was no increase in the frequency of duels. We found no significant differences in the overall rate of incidents after the introduction of stricter rule enforcement. However, the rate of head incidents and arm-to-head incidents was reduced.

Introduction

Football is one of the most popular team sports in the world. FIFA (Fédération Internationale de Football Association) has 208 member associations and about 240 million participating football players. The Football Association of Norway (NFF) consists of 1 933 clubs, which organizes 27 532 teams, 364 940 players of which 105 595 female players; which makes it the biggest sports federation in Norway (Haavik, 2013).

Laws of the Game

The modern game of European football was established in England with the foundation of the Football Association in 1863. It was decided that a game of football should be played between two teams with 11 players on each side. A goal was scored when the ball was kicked into a goal placed on each side of the pitch. Another important feature of the first rules of football, which was also an important injury prevention measure, was to ban kicking other players' legs. The sanction was to give the ball to the team of the offended player.

Football rules are divided into seventeen categories, and are called the Laws of the Game. They are governed by the International Football Association Board (IFAB). The Board meets once a year to discuss possible rule changes. Laws 5 and 6 include descriptions on how the referee and his assistants should enforce the Laws of the Game; in addition, Law 12 deals with fouls and misconducts. These three rules are the main rules with potential implications for the risk of injury (FIFA, 2011). Until recently, the Laws of the Game have provided given little guidance about how referees and match officials can contribute to injury prevention.

If the referees consider a challenge to be foul play, two disciplinary sanctions can be awarded. A player is cautioned (awarded a yellow card) if the challenge is regarded as "careless" (i.e. the player has shown a complete disregard to the danger to, or consequences for, his opponent). If the challenge is deemed as "using excessive force" (i.e. the player has far exceeded the necessary use of force and is in danger of injuring his opponent), the player is sent off (awarded a red card) (FIFA, 2011).

Injury prevention models

In 1992, van Mechelen introduced a four-step model for injury prevention research. Firstly, the extent of the injury problem has to be established, through a description of injury incidence and severity. Secondly, one has to identify the injury etiology, the risk factors and mechanisms for injury. The first two steps are mainly described employing prospective cohort studies (Bahr and Holme, 2003). Based upon the results from steps one and two, a potential preventive measure may be identified and introduced. Finally, as the fourth step, the efficacy of the preventive measure should be assessed, either by repeating the first step or ideally through a randomized controlled trial. Effective injury prevention studies are not necessarily easily implemented in daily life; therefore, Finch et al. (2006) expanded the four-stage sequence with two more steps emphasizing the need for implementation to ensure that preventive measures are widely adopted (Table 1).

Table 1. The Translating Research into Injury Prevention Practice framework for research leading to real-world sports injury prevention (Finch, 2006)

TRIPP Stage	Research need	Research process
1	Count and describe injuries	Injury surveillance
2	Understand why injuries occur	Prospective studies to establish etiology and mechanisms of injury
3	Develop "potential" preventive measures	Basic mechanistic and clinical studies to identify what could be done to prevent injuries
4	Understand what works under "ideal" conditions	Efficacy studies to determine what works in a controlled setting (e.g. RCT's)
5	Understand the intervention implementation context including personal, environmental, societal and sports delivery factors that may enhance	Ecological studies to understand implementation context
6	Understand what works in the "real world"	Effectiveness studies in context of real-world sports delivery (ideally in natural, uncontrolled settings)

Klügl et al. (2010) analyzed 11 859 articles on sports injury prevention, and classified them according to the TRIPP framework. They found that only 44% of the papers were original research articles. Another finding was that only 11% of the articles (n=1362) reported preventive measures; of these 33% reported on their efficacy (how the intervention works in a clinical trial) (n=460), 12% were implementation studies (n=162), and only 3% were effectiveness studies (how the intervention works in practice) (n=32). Thus, only 1% of all studies on sports injury prevention have evaluated implementation and effectiveness in an implementation context (Klugl et al., 2010). In addition, they found that studies on rules and regulations constituted only 0.6% (n=63) of the 11 859 articles retrieved, despite some of these studies showing considerable effects.

Injury definition

The risk of injury in sports has been evaluated for decades. The definition of what constitutes an injury has spanned from reporting physical complaints by players (Junge et al., 2004a) to hospital visits (Hoy et al., 1992) and insurance claims (Roaas and Nilsson, 1979), leading to diversity in both the overall injury risk and injury patterns, making it difficult to compare findings from different studies.

In 2006, F-MARC hosted a group of experts involved in the study of football injuries. The result was a consensus statement that aimed at establishing definitions and methodology, implementation and reporting standards for studies of injuries in football (Fuller et al., 2006). The consensus statement defines an injury as "any physical complaint sustained by a player that results from a football match or football training", irrespective of the need of medical attention or time loss from football activity. An injury that results in a player being unable to take a full part in future football training or match is referred to as a "time-loss" injury, an injury that results in a player receiving medical attention is referred to as a "medical-attention" injury (Fuller et al., 2006).

All injury definitions have certain limitations and advantages that need to be acknowledged. The "time-loss" definition is highly dependent upon training frequency; thus, minor injuries can easily be missed when activity is not daily, which might be the case at the amateur and youth level. In addition, the "time-loss" definition is sports-specific; a football player might play with a broken finger, whereas a volleyball player might be prevented from participation. Minor injuries, as blisters and abrasions, are likely to be missed using a "time-loss" definition, but will be captured by the "physical-complaint" definition. Access to medical staff, importance of the match and frequency of activity might influence the timing of return to full football activity and therefore the length of absence with a "time-loss" definition. A "medical staff" definition is highly dependent on access to health care, and therefore not tailored for youth and amateur football. In other words, the rate of injury reported in a study is dependent upon the definition, as players will not always miss training or seek medical assistance because of a physical complaint. It can therefore be expected that a "physical complaint" definition will yield a higher injury rate than a "medical-attention" definition, and "time-loss" definition will result in the lowest registered injury rate (Bahr, 2009).

Another important part of injury registration is the recording of severity. Several different definitions have been used over the years: nature and duration of injury, sporting time lost, working time lost, the presence of permanent sequelae, type of treatment or costs (van Mechelen et al., 1992). The most commonly used severity definition in the field of sports injury research has been the number of days of absence from activity. The National Athletic Injury Registration System (NAIRS) classified injuries as minor (1-7 days), moderate (8-21 days) and severe (>21 days) (van Mechelen et al., 1992). The FIFA consensus statement categorized injury severity into slight (0 days), minimal (1-3 days), mild (4-7 days), moderate (8-28 days) and severe (>28 days) (Fuller et al., 2006).

Injuries have commonly been separated into two groups; acute and overuse injuries. An acute injury has been defined as an injury resulting from a specific, identifiable event and an overuse injury as one caused by repeated microtrauma without a single, identifiable event responsible for the injury (Fuller et al., 2006). Others have defined overuse injuries as injuries with an insidious onset with a gradually increasing intensity of discomfort without an obvious trauma (Arnason et al., 2004a). However, it has been argued that a time-loss definition is not suitable for the reporting of overuse injuries (Bahr, 2009). Overuse injuries are due to repetitive low-grade forces beyond the tolerance of the tissues, which in most cases repair without verifiable clinical symptoms (Bahr, 2009). Nevertheless, if the process exceeds the tissues inherent ability to repair and adapt, it might result in a noticeable overuse injury with corresponding symptoms and absence from activity, thus, captured through a time-loss definition.

The risk of injury has generally been expressed as incidence, which is defined as the number of new cases of an injury in a defined population in the course of a given time period. Injury incidence is commonly reported as the number of injuries per 1000 player hours of exposure to football.

Injury registration methods

Few continuous surveillance systems have been established in the world of sports. The NCAA injury surveillance system was established 30 years ago, and is the largest ongoing athletic injury database in the world (Dick et al., 2009). It monitors formal team activities, numbers of participants, and time-loss injuries from the first day of formal preseason practice to the final postseason contest for 16 collegiate sports. A similar system is the Canadian Intercollegiate Sports Injury Registry (CISIR) (Meeuwisse and Love, 1998). In order to make ice hockey safer the International Ice Hockey Federation (IIHF) established an injury surveillance system in 1998, where team physicians collect injury information after each match during championships (International Ice Hockey Federation, 2011). The International Olympic Committee (IOC) has also developed an injury surveillance system, practical for both individual and team sport and for events with one sport and several sports (Junge et al., 2008). Similar reporting systems have been established for several seasons or tournaments in skiing and snowboarding (Flørenes et al., 2011), rugby (Bathgate et al., 2002; Best et al., 2005), team handball (Langevoort et al., 2007), cricket (Orchard et al., 2005) and athletics (Alonso et al., 2009).

The first continuous injury surveillance system in football was implemented during the World Cup in France in 1998 (Junge et al., 2004b). The same methods are now in use in all FIFA tournaments, male and female. The medical staff of each country registers medical reports on a daily basis, and the medical forms are collected by a FIFA medical officer after each match. UEFA has taken a similar approach (Hägglund et al., 2005a). Prospective registration from club football over more than one season have been conducted in Norway, England, Sweden and in the Champions League (Hawkins and Fuller, 1999; Hägglund et al., 2006; Andersen et al., 2004d; Ekstrand et al., 2011c; Eirale et al., 2013a).

Injury incidence is not only dependent on the injury definition, but the registration method used will also have a significant impact on the injury incidence reported (Inklaar, 1994a; Dvorak and Junge, 2000; Fuller et al., 2006). Over the last four decades, many different methods have been used to record injuries in sports, leading to a substantial discrepancy in the injury incidences reported (Fuller et al., 2006; Clarsen et al., 2012; Bahr, 2009).

Previous studies from football, among preschool children and physical education students have shown that more injuries are recorded by prospective injury registration compared to retrospective interviews (Junge and Dvorak, 2000; Twellaar et al., 1996; Fonseca et al., 2002). Prospective injury registration is not complete, but the reliability of retrospective injury registration is poorer (Twellaar et al., 1996). Czech football clubs were followed on a weekly basis by a physician who recorded injuries sustained by their players. In addition, the players filled out a questionnaire after the 12-month season self-reporting injuries they had sustained (Junge and Dvorak, 2000). The study group found that there was significant recall bias associated with retrospective player interviews, especially regarding mild injuries sustained close to one year prior to the interviews (Junge and Dvorak, 2000). The localization and circumstances of injury were similar in both the prospective and retrospective data collection (Junge and Dvorak, 2000).

The consensus statement on injury definitions and data collection procedures for studies of injuries in football emphasized that injury registration should be done prospectively, and conducted by a member of the medical staff (Fuller et al., 2006). Nevertheless, medical staff recording is not necessarily the best injury registration method in all settings. A study among elite alpine skiers and snowboarders found that only 61% of all recorded injuries were reported by the medical staff, and that only 6% of the injuries recorded by the medical staff were missed by retrospective player interviews (Flørenes et al., 2011). In addition, in sports were the athletes do not have a close follow-up from the medical staff, medical staff reporting could lead to a substantial underreporting of injuries. Nilstad et al. (2012) found that medical staff reporting missed approximately 2/3 of all injuries, and 50% of all severe injuries compared to individual self-reported registration through text messaging in female elite football. Thus, injury recording systems ought to be tailored, not only the sport, but also the level of play and other factors potentially influencing the injury recording system.

In addition to the injury registration, recording of exposure is essential for studies evaluating injury incidence. Exposure registration in football can either be recorded on a team basis or individually. Team-based exposure registration is typically conducted by multiplying the hours of training session or match play with the number of participating players. In contrast, individual exposure registration allows for the fact that exposure to match play and training can vary between players in the same team. Individual exposure registration would allow the study group to control player attendance versus injury reports received, and should serve to increase the capture rate (Fuller et al., 2006; Hägglund et al., 2005a).

The quality of the results based on an epidemiological study is dependent on the accuracy and reproducibility of the information collected. To interpret results from injury registration it is important to know the validity and reliability of the injury registration system. However, it is not known whether a routine injury surveillance system captures all time-loss injuries suffered by players. This question was therefore addressed in Paper I.

Injury risk in male football

Injury incidence

As a result of the combination of high participation rates in football and the risk of injury, football is responsible for between one-fourth and one-half of all sports-related injuries in Europe (Keller et al., 1987; Hoy et al., 1992; Inklaar et al., 1996; Bahr et al., 2003). To examine the injury incidence a literature search on PubMed was conducted using the following search terms: (injury or injuries) and incidence and (football or soccer) and (male or adult) and epidemiology and prospective. The reference lists of retrieved articles were checked manually for other potentially relevant studies. Table 2 summarizes the injury incidences from studies on adult male football at both the club and national team level.

Nineteen studies have reported the rate of injury among adult male footballers playing at the club level. All studies were prospective, and included injury registration from more than one club, and for at least half a season. These studies have shown that the injury incidence in football is high; between 65% and 82% of the players will sustain at least one injury during a season (Arnason et al., 2004a; Nielsen and Yde, 1989). In a recent study by Ekstrand et al. (2011c) each player at the highest professional level on average sustained two injuries per season. Drawer and Fuller (2002) have demonstrated that the injury incidence during matches is approximately 1000 times higher than high-risk industrial occupations (i.e. construction and mining).

Studies have shown that there is a significantly higher incidence of injury during match play compared to training. The injury incidence has been reported to range between 1.8 and 11.8 injuries per 1000 player-training hours, while the match injury incidence in adult male football ranges from 11.3 and 35.3 injuries per 1000 player-match hours (Table 2).

From studies at the elite level, using a time-loss definition, the training injury incidence is reported to range from 1.9 to 11.8 per 1000 player-training hours and the incidence of time-loss match injuries ranges from 13.0 to 34.8 per 1000 player-match hours (Table 2).

Recent studies have found that on a team level, a low incidence of injuries and high match availability were associated with better team performance (Hägglund et al., 2013; Eirale et al., 2013b; Arnason et al., 2004a).

The risk of injury at the senior national team level is slightly higher compared to the club level. The injury rate varies between 40 and 51 injuries per 1000 player-match hours during European Championships, World Cup and Olympic Games matches (Table 2).

Few studies have been carried out over several consecutive seasons in order to monitor changes in injury incidence and injury circumstances and injury pattern over time. Therefore, to monitor the incidence of injury and injury pattern in Norwegian male professional football over time, a continuous injury registration system was established in 2000. The results from six consecutive seasons are presented in Paper II.

Table 2. Summary of injury incidence and injury characteristics in prospective studies of male adult football players at club level

Reference	Hägglund (2003)	Ekstrand & Gillquist (1983)	Nielsen & Yde (1989)	Poulsen (1991)	Engstrøm (1990)	Arnason (1996)	Lüthje (2007)	Hawkins & Fuller (1999)	Hawkins (2001)	Morgan (2001)	Arnason (2004)
Country	Sweden	Sweden	Denmark	Denmark	Sweden	Iceland	Finland	England	England	USA	Iceland
Study period	1982	1980	1986	1986	-	1991	1993	1994-97	97-99	1996	1999
Level of play	Elite	Amateur	Amateur	Elite/amateur	Elite	Elite	Elite	Professional	Professional	Professional	Elite
Injury definition	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Medical attention	Time-loss^	Time-loss+	Medical attention	Time-loss*
No of injuries	236	256	109	57	85	85	317	578	6030	399	244
Players injured (%)	76	69	82	-	75	71	65	-	-	-	56
Acute injuries (%)	-	69	66	65	65	91	92	95	-	-	84
Overuse injuries (%)	-	31	34	35	35	9	8	5	-	-	16
Re-injury	-	-	42	-	-	35		22	7	-	
Injury incidence											
Match	20.6	16.9	14.3	20.3	13	34.8	11.3	25.9	-	35.3	24.6
Contact (%)		59%	-	-	-	44%		49%	-		-
Training	4.6	7.6	3.6	4.5	3.0	5.9	1.8	3.4	-	2.9	2.1
Severity											
Minor	68	62	46	-	27	-		52	33	60	38
Severe	9	11	35	-	34	-		11	23	14	23[A]
Injury location											
Head/neck	-	-	-	4	-	-	9	2	7	-	3
Upper limb	-	-	-	2	-	-	6	3	3	-	6
Trunk	-	5	-	2	2	-	9	8	3	-	7
Lower limb	-	88	84	93	93	82	76	88	87	77	83
Hip/groin	-	13	22	19	12	-	2	13	12	11	13
Thigh	-	14		18	8	-	22	23	23	10	24
Knee	-	20	18	23	33	-	19	15	17	21	16
Lower leg	-	12	-	2	11	-	8	14	13	-	13
Ankle	-	17	36	19	22	-	17	17	17	18	9
Foot	-	12	8	21	7	-	8	6	6	-	5
Injury type											
Joint & lig.	-	31	48	42	36	22	-	20	25	-	18
Muscle & tend.	-	41	37	30	45	29	-	42	42	21	31
Contusion	-	20	9	12	13	20	32	18	13	-	21
Fracture	-	4	6	7	4	-	7	4	4	-	-
Concussion	-	-				-	1	-		-	.

**One training session or match; ^the day after the injury; +>48 hour; A>21 days; AT- athletic trainer*

Table 2. Summary of injury incidence and injury characteristics in prospective studies of male adult football players at club level

Reference	Andersen (2004)	Hägglund (2003)	Hägglund (2005)		Waldèn (2005)		Waldèn (2005)	Hägglund (2006)	Hägglund (2009)	Engebretsen (2008)	Ekstrand (2011)
Country	Norway	Sweden	Denmark	Sweden	Sweden		Sweden	Sweden	Sweden	Norway	CL
Study period	2000		2001		2001		2002	2002	2005	2004	2001-08
Level of play	Professional	Professional	Professional		Professional		Professional	Professional	Professional	Amateur	Professional
Injury definition	Time-loss^	Time-loss*	Time-loss*		Tissue injuries	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Time-loss*
No of injuries	121	715	395	481	765	715	658	1189	548	505	4483
Players inj. (%)	-	77	81	67	77	77	85	76	79	56	-
Acute (%)	-	-	61	63	65	63	63	62	-	70	72
Overuse (%)	-	-	39	37	35	37	27	38	-	30	28
Re-injury	-	-	30	24		22	15	-	19	-	12
Injury incidence											
Match	21.5	25.9	28.2	26.0	27.2	25.9	30.5	27.2	28.1	12.1	27.5
Contact (%)						-			-	52	-
Training	-	5.2	11.8	5.0	5.7	5.2	5.8	5.7	4.7	2.7	4.1
Severity											
Minor	44	60	67	60	-	60	56	61	65	43	48
Severe	26[A]	9	12	9	-	9	15	11	9	16	16
Injury location											
Head/neck	-	-	-	3	-	2	3	3	2		2
Upper limb	-	-	-	2	-	-	-	2	3		4
Trunk	-	-	7	7	-	6	6	8	8		7
Lower limb	75	-	89	87	-	88	86	87	88	-	87
Hip/groin	-	-	15	16	-	16	12	17	18	12	14
Thigh	-	-	22	23	-	23	23	23	23	15[H]	24
Knee	-	-	21	15	-	16	20	17	16	12	18
Lower leg	-	-	11	16	-	15	11	13	10	-	11
Ankle	-	-	13	10	-	10	14	10	14	11	14
Foot	-	-	7	7	-	8	6	7	7	-	6
Injury type											
Joint & lig.	-	-	23	16	-	17	24	17	18	-	18
Muscle & tend.	-	-	21	26	-	22	26	-	44	-	42
Contusion	-	-	14	17	-	17	16	15	18	-	17
Fracture	-	-	2	2	-	3	-	3	3	-	4
Concussion	-	-	-	-	-	-	-	-	1	-	-

**One training session or match; ^the day after the injury; [H] Reported only hamstring injuries; CL = Champions League*

Table 2. Summary of injury incidence and injury characteristics in prospective studies of male adult football players at national team level

Reference	Ekstrand (2004)	Junge (2004)	Yoon (2004)		Junge (2004)	Junge (2004)	Junge (2006)	Waldèn (2007)	Dvorak (2007)		Hägglund (2009)	Dvorak (2011)	
Tournament	NT	WC	Asian Cup		Olympics	WC	Olympics	EC	World Cup		EC	World Cup	
Study period	1991-97	1998	2000		2000	2002	2004	2004	2006		2008	2010	
Injury definition	Time-loss*	Physical complaint	Physical complaint	Time-loss	Physical complaint	Physical complaint	Physical complaint	Time-loss*	Physical complaint	Time-loss^	Time-loss*	Physical complaint	Time-loss^
No of inj.	71	149	133	47	116	171	77	45	145(45.9^{TL})	97	56	229	144
Players inj. (%)	-	-	-	-	-	-	-	11	-	-	14	-	-
Acute (%)	80	-	-	-	-	-	-	80	-	-	73	-	-
Overuse (%)	20	-	-	-	-	-	-	20	-	-	27	-	-
Re-injury		-	-	-	-	-	-	???	-	-	7	-	-
Injury incidence													
Match	30.3	72.8	139.5	49.3	113.4	81 (51^{TL})	73 (29^{TL})	36	68.7	45.9	41.6	61.1	40.1
Contact(%)	-	-	80	-	91	73	86		73	-	73	65	-
Training	-	-	-	-	-	-	-	2.1	-	-	2.8	7.9	4.4
Severity													
Minor	-	-	-	83	85	80^{TL}	81 ^{TL}	60	-	50	55	-	81
Severe	-	-	-	4	4	3^{TL}	7 ^{TL}	27	-	5	23	-	3
Injury location													
Head/neck	-	15	8	6	21	15	14	0	9	4	-	8	5
Upper limb	-	9	4	2	3	5	6	9	8	5	-	7	6
Trunk	-	9	14	15	9	4	8	7	10	11	-	8	6
Lower limb	-	62	75	76	59	77	72	83	74	82	-	76	83
Hip/groin	-	-	2	2	-	6	5	11	5	5	-	4	6
Thigh	-	20	11	17	14	18	17	22	15	17	-	24	26
Knee	-	23	19	23	10	13	16	11	12	18	-	11	10
Lower leg	-	6	17	11	23	17	18	11	21	20	-	16	15
Ankle	-	13	20	17	12	15	12	15	17	17	-	14	14
Foot	-	-	6	6	-	8	4	13	4	5	-	7	9
Injury type													
Joint & lig.	-	12	17	30	13	14	9	22	21	25	-	14	17
Musc & tend.	-	25	10	8	3	23	7	27	13	20	-	25	28
Contusion	-	41	62	38	65	50	71	11	51	45	-	37	30
Fracture	-	4	0	0	1	2	1	9	1	1	-	2	3
Concussion	-	1	1	2	1	2	0	-	1	1	-	1	1

*TL Time-loss; *One training session or match; ^the day after the injury*

Injury pattern

In table 2, injury type and body location have been reclassified according to the consensus statement (Fuller et al., 2006) to facilitate comparison between different studies. The majority of injuries recorded have an acute onset, with overuse injuries accounting for 9% to 39%. However, as mentioned, a significant proportion of overuse injuries do not lead to time loss from sports participation; players often continue training and playing games even when limited by pain and reduced function. Studies based on an injury definition requiring time loss from football therefore lead to a substantial underestimation of overuse injuries (Bahr, 2009).

More than 75% of all injuries affect the lower extremities, mainly the thigh, knee, lower leg and ankle. Early studies of the injury risk among male elite players found that the knee was the most common injury location. Recent studies indicate a possible shift towards an increased proportion of thigh injuries. This is also supported by the observation of a parallel increase in the proportion of muscle and tendon injuries compared to injuries to joints and ligaments.

Studies from the national team level indicate a slightly different injury pattern compared to the club level with more time-loss injuries to the head (6-21%) and lower leg (11-20%). There also seems to be an increased representation of contusion injuries (38-50%). It must be noted that studies from the national team level have used a "physical-complaint" definition, thus making it difficult to compare to studies from the club level using a "time-loss" definition.

Table 2 shows that the difference in injury incidence and injury pattern varies significantly between different studies. The training incidence varies with a factor of ten, and the match injury incidence with a factor of three. A recent study from Champions League found an increased overall and training injury incidence among teams from northern parts of Europe, this was thought to be explained by climatic differences (Waldén et al., 2011a). To date ethnicity and injury incidence and pattern has not been evaluated thoroughly. In addition, differences in injury recording methods and design could lead to differences in injury incidence and pattern. A weakness of the studies in Table 2 is the lack of validation; none of the studies have tested the validity and reliability. Thus, there is a possibility of over-/underestimation of the injury incidence in the different studies.

Injury severity

Severity of injury has in the literature most commonly been presented as the duration of absence from training and match play. As shown in table 2, between 27-69% of all injuries are minor, i.e.

players are able to return to full activity within a week. Severe injuries, leading to absence from training over 4 weeks, are responsible for between 11-35% of all injuries. The greater part of severe injuries are sprains, most commonly to the knee joint, fractures and hamstring strains (Chomiak et al., 2000; Ekstrand et al., 2011c; Waldén et al., 2005a).

Long-term consequences

Acknowledging the high risk of injuries in football, a question is the potential for long-term sequelae resulting from these injuries. Severe injuries such as ACL tears, but also in some cases strains and other sprains may be career-ending. In an English survey, Drawer and Fuller (2001) showed that 2% of professional football players in England retired each year due to injury and nearly 50% of former players responded that they had retired due to injury. Most of the players reported chronic problems as cause of retirement (58%), most commonly of the knee, lower back and hip (Drawer and Fuller, 2001). Of the acute injuries, most were knee injuries, followed by ankle and lower back. On the amateur level, social reasons was the most common explanation for retirement; nevertheless, 22% retire because of injury problems (Ekstrand et al., 1990).

It has been well documented that knee injuries, especially ACL injuries, increase the risk for early development of osteoarthritis (Roos, 1998; Drawer and Fuller, 2001; Turner et al., 2000; von Porat et al., 2004; Øiestad et al., 2009; Myklebust and Bahr, 2005), with the knee reported as the most commonly affected joint. The most important risk factor for early development of osteoarthritis is a history of previous injury to the affected joint. Combined knee joint injuries have a higher prevalence of osteoarthritis development compared to isolated ACL injuries (Øiestad et al., 2009).

In addition, studies have found an increased incidence of osteoarthritis among former football players compared to the normal population, indicating an inherent risk of osteoarthritis development among football players (Klunder et al., 1980; Roos et al., 1994; Lindberg et al., 1993; Larsen et al., 1999). In contrast, a recent study found no difference in the prevalence of low back pain among former endurance athletes with specific back loading compared with non-athletes. This indicates that years of prolonged and repetitive flexion or extension loading in endurance sports do not lead to more low back pain (Foss et al., 2012).

With a time-loss injury definition, the proportion of head/neck injuries ranges from 2% to 9% (Table 2), however, the definition of concussion has varied, as has the registration methods, thus, the incidence of concussion is thought to be underreported in most studies (Straume-Naesheim et al., 2005). The acute effect of concussion on neuropsychological functions is widely discussed.

A meta-analysis has not been able to identify neuropsychological deficits attributable to minor head traumas beyond 7 days post impact for sports-related concussion (Belanger and Vanderploeg, 2005). However, several studies have found an impaired cognitive level after concussion. Straume-Næsheim et al. (2009) found through a case-control study that players suffering minor head traumas had reduced neuropsychological performance. This is supported by studies from American football and Association football (Guskiewicz et al., 2007; Matser et al., 1998; Matser et al., 1999; Matser et al., 2001). A study from Pellmann et al. (2004) found that around 2% of all athletes suffering from concussion have signs of post-concussion syndrome (PCS). The main physical symptom of post-concussion syndrome (PCS) is headache, other symptoms includes reduced concentration and memory, anxiety, nausea and dizziness lasting beyond three months after the impact. Chronic neurocognitive impairment can present in post-concussion syndrome or after a symptom-free interval. In addition, it has been showed that players with a history of concussion have a higher incidence of reduce neurocognitive functioning and increased depression rates (Guskiewicz et al., 2007).

Magnetic resonance imaging studies have found abnormal brain activation in sports-related concussion. In addition, autopsies have shown long-term neurological sequelae of concussion as chronic traumatic encephalopathy. Chronic traumatic encephalopathy, a post-mortem diagnosis, is linked with symptoms of dementia, aggression, depression appearing many years and even decades after the concussion episode. CTE have also been found among athletes without reported concussion episodes, indicating a possible risk with sub-concussive blows. The studies of chronic traumatic encephalopathy and chronic neurocognitive impairment to date are small, and large-scale, epidemiological studies are required to clearly understand the causes and consequences of concussions (Harmon et al., 2013).

Risk factors for injury

An important part of van Mechelen's four-step sequence of injury prevention research is to establish the etiology, i.e. the mechanisms and risk factors for sports injuries (van Mechelen et al., 1992). A variable associated with injury is called a risk factor. Traditionally, risk factors are separated into two categories; internal and external (Meeuwisse, 1994). Internal risk factors are individual biological and psychosocial characteristics predisposing a person to the outcome of a musculoskeletal injury (Meeuwisse, 1994). External risk factors are independent of the injured person and are principally related to the type of activity during the incident of injury (Meeuwisse, 1994). Bahr & Holme (2003) outline three different methods to study risk factors for sports injuries: case-control studies, cohort studies and intervention studies (preferably RCTs) (Bahr and Holme, 2003). The preferable study design is the prospective cohort study, as it can provide direct and accurate estimates of incidence and relative risk (Bahr and Holme, 2003).

In 1994, Meeuwisse proposed a multifactorial model to study the causation of sports injuries. Internal risk factors (e.g. age, gender, injury history, flexibility) are predisposing, but seldom sufficient to cause injury (Meeuwisse, 1994). External risk factors have an impact from without, and include factors such as surface, rules, equipment and weather (Meeuwisse, 1994). Thus external risk factors, as shoe-surface interactions and protective equipment, can modify the internal risk factors, and together determine injury proneness. However, internal and external factors are usually not sufficient to explain an injury; the final piece in the puzzle is the inciting event (Meeuwisse, 1994). Later this model was modified by Bahr & Krosshaug (2005), concluding that there is a need for detailed information about the inciting event to fully understand the causes of injury (figure 1). Hence, information about the playing situation, player and opponent behavior, as well as a description of whole body and joint biomechanics at the time of injury may provide important clues as to how injuries may be prevented. However, to address the potential for prevention, information about injury mechanisms must be considered in a model that takes into account how internal and external risk factors can modify injury risk (Bahr and Krosshaug, 2005).

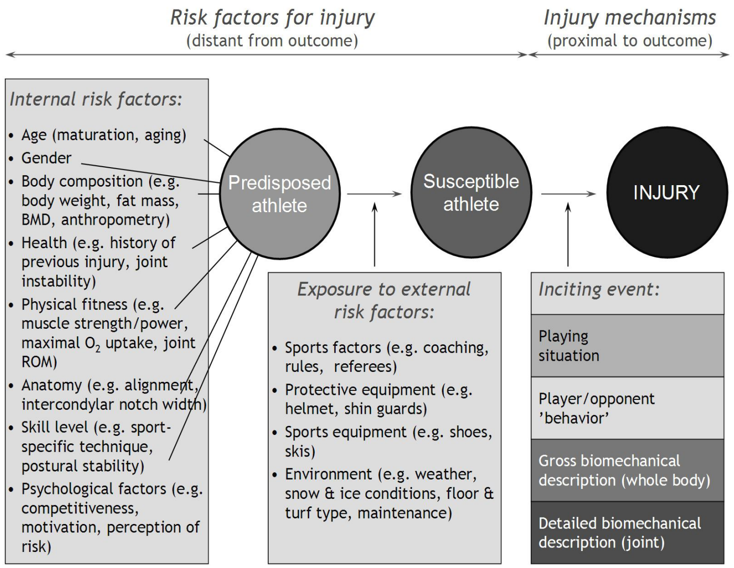

Figure 1. Multifactorial model for injury mechanism (Bahr & Krosshaug, 2005)

Meeuwisse (2007) argued that these current models consist of a linear paradigm, that events follow each other sequentially from a starting point to an end point, and that this does not mirror the true nature of sport injuries. Meeuwisse (2007) therefore introduced the need for a dynamic approach, where a risk factor may be altered as the athlete participates and adapts to the environment or to potentially injurious situations without sustaining an injury.

Whether internal or external, a risk factor is either modifiable or non-modifiable. Modifiable refer to those which can be altered by injury prevention strategies (Emery, 2005). In contrast, non-modifiable risk factors are not affected by injury preventive measures. However, non-modifiable risk factors may influence the relationship between modifiable risk factors and injury (Meeuwisse, 1991). Some potential risk factors for injury in sports are listed in table 3 (Emery, 2005). In the following section some important injury risk factors will be discussed.

Table 3. Potential risk factors for injury in sports (Emery. 2005).

	External risk factors	Internal risk factors
Non-modifiable	Sport played (and level of play)	Previous injury
	Position played	Age
	Weather	Gender
	Time of season/time in match	
Potentially modifiable	Rules	Fitness level
	Playing time	Strength/flexibility/balance/proprioception
	Playing surface	Biomechanics
	Equipment (protective/footwear)	Psychological/social factors

Non-modifiable risk factors

Age

Youth football

A study from Norwegian youth football found a higher injury incidence among 13 to 16 year old players compared to children aged 6 to 12 years (Froholdt et al., 2009). Furthermore, it has been shown that players aged 14 to 16 had a higher injury risk than 16 to 18 years old players (Peterson et al., 2000; Le et al., 2008).

Senior football

A study of injury risk factors in Icelandic football Arnason et al. (2004) found, using a multivariate logistic regression analysis, that older players ($\geq$ 29 years) had a significantly higher risk of injuries compared to younger players. This was recently supported by a study from Champions League, which found that newcomers to professional football had a lower overall rate of injury compared to established players (Kristenson et al., 2013b). However, newcomers had a higher rate of stress-related bone injuries (Kristenson et al., 2013b). Two studies have found that older players have an increased risk of sustaining hamstring strains (Hägglund et al., 2006; Woods et al., 2004; Arnason et al., 2004a). In contrast, no such association was found in a study of football on the American continent (Morgan and Oberlander, 2001).

Anthropometrics

Anthropometrics can be classified both as a modifiable (weight) and a non-modifiable (height) risk factor. Most studies have found no significant association between different anthropometric variables (height, weight, BMI) and risk of injury in male adult football (Arnason et al., 2004a; Hägglund et al., 2006). In contrast, Dvorak et al (2000) found higher injury rates among players with low body fat (<7.7%).

Gender

Few have compared the injury incidence between male and female football players in the same study. Studies using the same injury definitions and study design have observed a higher injury incidence among male football players for both training and matches (Hägglund et al., 2009; Fuller et al., 2007b; Fuller et al., 2007a). However, Hägglund et al. (2009) found a similar incidence of moderate and severe injuries between genders, even though male players had a higher incidence of injuries leading to absence less than one week. It should be kept in mind that the female players had a lower number of weekly sessions, and the female clubs had smaller medical teams; accordingly, the injury incidence among female football players in this study was probably underestimated due to underreporting. The reduced medical support for female players may also lead to delay in diagnosis and treatment of injuries, leading to longer absence from football activity. In epidemiological studies of injury risk in female football, the match injury incidence varies from 14.3 to 23.6 and the injury incidence from 3.1 to 3.7 when using time-loss registration by medical staff (Ostenberg and Roos, 2000; Tegnander et al., 2008). Thus, the injury incidence in female club football seems to be somewhat lower compared to male club football.

The other studies comparing the risk of injury between genders using the same methodology have been conducted at the national team level, and during tournament play. These studies have shown discrepant results. One study showed a lower incidence of injuries in female football (Junge et al., 2004b), while two more recent studies found no significant difference in injury incidence between the two genders (Junge et al., 2006; Waldén et al., 2007). In a review it was documented that female football players have a 2-3 times higher risk of ACL injuries compared to men; female players are also generally younger when sustaining an ACL injury (Waldén et al., 2011b).

Previous studies have shown that a higher proportion of injuries among male players are due to player-to-player contact, in particular during matches (Hägglund et al., 2009; Junge et al., 2004b).

Level of play

The risk of injury tends to be higher during international matches compared to national league matches (table 2). However, there seems to be no significant difference in the risk of injury between different levels of professional football (Champions League compared to domestic league football) (Arnason et al., 2004a; Hägglund et al., 2005b; Ekstrand et al., 2011c). Few studies have compared the risk at different levels of play using the same methods at the same time. In a study from Danish football no significant difference was detected in the risk of injury between high-skilled and low-skilled players (Poulsen et al., 1991). In contrast, a study from Czech football found a significantly higher risk of injury among low-level players both at the senior and youth level (Peterson et al., 2000). In contrast, Soligard et al. (2010) found in a Norwegian study that high skill was a significant risk factor for injury in female youth football.

Previous injury

Many different definitions of re-injury have been used over the years, leading to substantial differences in the reported risk of re-injury. Studies where re-injury has been defined as an injury of the same type and at the same site within 2 months after return to full participation from the index injury, have found that the proportion of re-injuries ranges between 12 and 35% (Ekstrand et al., 1983; Ekstrand et al., 2011c). Other studies, without any time limit, have found a re-injury rate between 22% and 42% (Hawkins and Fuller, 1999; Nielsen and Yde, 1989). In addition, studies have shown that re-injuries cause a longer absence from football activity than index injuries (Ekstrand and Gillquist, 1983; Waldén et al., 2005a; Ekstrand et al., 2011c).

Previous injury has been identified as a risk factor for new injuries to the knee, groin, ankle and thigh (Arnason et al., 2004a; Hägglund et al., 2006; Engebretsen et al., 2010b; Engebretsen et al., 2010c; Engebretsen et al., 2010d; Waldén et al., 2006). Studies in both football and other sports have shown that previous ankle injury is a risk factor for new ankle sprains. Arnason et al. (2004)

found that players with a history of ankle sprains had more than five times higher risk of a new ankle sprain. Engebretsen et al. (2010) found that the number of previous ankle sprains proved to be a significant predictor of new ankle injuries (Engebretsen et al., 2010a); this was supported by an English analysis of ankle sprains (Woods et al., 2003). In contrast, a risk factor study from Swedish football found no relationship between previous ankle sprains and the risk of a new injury (Hägglund et al., 2006).

Whether previous injury is a non-modifiable or modifiable factor can be argued. An injury might lead to muscle weakness or reduced proprioception, factors that could be improved through tailored strength programs or balance programs, thus reducing the effect of previous injury on re-injury, and making previous injury a modifiable risk factor. The high proportion of re-injuries indicates that insufficient rehabilitation and too early return to football activity are possible risk factors for injury. In addition, the risk of re-injury among players at the highest level of club football (Champions League) is the lowest recorded (12%). This was explained by bigger medical teams, providing more personalized rehabilitation after injuries (Ekstrand et al., 2011c).

Time in match and training

Several studies have reported that more injuries occur towards the end of each half (Engström et al., 1990; Hawkins and Fuller, 1999; Junge et al., 2004a). Ekstrand et al. (2011) found an increased incidence of acute injuries, and also in the subcategories strains, sprains and contusions over time in both the first and the second half. It has been shown that most hamstring and ankle injuries are sustained towards the end of matches (Kofotolis et al., 2007; Woods et al., 2004). These results suggest that fatigue could be a risk factor. Other studies contradict these results, and find no significant different risk of injury between the two halves or during the halves (Arnason et al., 2004a; Chomiak et al., 2000).

Time in season

The injury incidence has been reported to vary over different periods of the season, with peaks during the preseason, the mid-season breaks and intensive match periods (Engström et al., 1990; Hawkins and Fuller, 1999; Junge et al., 2004a). An audit of preseason injuries in English professional football found that players were at greater risk of slight and minor injuries, overuse injuries and lower leg (Achilles tendon) injuries during the preseason (Woods et al., 2002). This finding was recently supported by Ekstrand et al. (2011), who documented an increased risk of overuse injuries and lower risk of traumatic injuries during the preseason. That congested match periods have a higher risk of injury is supported by Dupont et al. (2010). They found, in a study of the effect of playing two matches per week vs. one, that the recovery time was sufficient to maintain the level of physical performance, but that injury rate increased significantly when playing two matches per week (Dupont et al., 2010). However, a recent study found no difference in injury risk over a period of 26 days with 8 matches compared to a period with less matches (Carling et al., 2012). One study has shown that most ankle injuries occur during the first two months of the season (Kofotolis et al., 2007). In Norway, the league starts in April and end in November, with the pre-season starting in January. In contrast, most European leagues start in August and end in May, with a 6-week preseason. In Paper II, we wanted to evaluate whether there the risk of injury is different during the preseason compared to the competitive season.

Modifiable risk factors

Foul play

Between 15% and 29% of all acute match injuries at the elite level result from foul play (i.e. a free kick given by the referee, as reported by the medical staff). A British study found that nearly 60% of the remaining injuries were due to physical contact between players; whether the player-to-player contact was a violation of the rules or not was not stated (Hawkins and Fuller, 1999). In a study of psychological characteristics of football players, Junge et al. (2000) found that players have insufficient respect for the Laws of the Game. In addition, nearly all players were ready to commit a "professional foul" if necessary and a majority stated that concealed fouls were a part of the game.

Andersen et al. (2004) showed that less than one-third of injuries identified on video and only 40% of situations with a propensity for injury resulted in a free kick being awarded. In addition they showed that only 10% of all incidents led to a yellow or red card being awarded, and only about 10% of the yellow and red cards awarded during the season were given in situations with a high propensity for injury. The authors therefore concluded that player cautions and expulsions are primarily used for rule violations other than those associated with a high risk of injury (Andersen et al., 2004d). This was verified through a retrospective blinded evaluation of the referee decisions, which showed a good correlation (85%) between the referee panel and decisions of the match referee. The authors therefore concluded that there may be a need for an improvement of the Laws of the Game or their application to protect the players from injury (Andersen et al., 2004b). Thus, in Paper V we have evaluated whether a stricter enforcement of the existing rules can reduce the potential for injuries in male professional football.

Fitness

Muscle strength deficiency has been proposed as one of several risk factors for hamstring injury. A small Swedish study (n=30) showed that low eccentric muscle strength was a significant risk factor for hamstring strains (Askling et al., 2003). Arnason et al. (2004) found no association between concentric quadriceps strength and the risk of quadriceps strains. Croisier et al. (2008) have shown that a low hamstring/quadriceps ratio was a predictor of hamstring injury. It has also been documented that players with untreated side-to-side differences in isokinetic hamstring parameters had an increased risk of hamstring injuries compared to those without differences between the two thighs (Croisier et al., 2008). Two studies found no association between the risk of injury and endurance in male senior football (Dvorak et al., 2000; Arnason et al., 2004a). However, as previously stated, it has been shown that muscle injuries are more frequent towards the end of each half. Thus, fatigue might represent an important risk factor for muscle injuries (Ekstrand et al., 2011c; Ekstrand et al., 2011b; Hawkins and Fuller, 1999).

Psychological factors

Several studies have found that athletes with previous stressful life-events have an increased risk of injury (Junge et al., 2000; Steffen et al., 2009; Rogers et al., 2003; Dvorak et al., 2000). Athletes reporting low levels of social support and coping skills have an increased risk of injury (Smith et al., 1990; Johnson and Ivarsson, 2011). Other studies have found no relationship between coping strategies and injury (Steffen et al., 2009; Ivarsson et al., 2013). A recent study from Ivarsson et al. (2013) found that the traits anxiety, negative life-events, stress and high levels of daily hassle were predictors for injury; however, no relationship between coping strategies and injury were detected. Previously, it has been shown that injured players tend to be more risk-seeking (Junge, 2000). It has been shown in both youth and senior football that previously injured players have a perception of a performance climate (Steffen et al., 2009); however, in the prospective part of the same study a mastery climate was a risk factor for new injury.

Surface

Grass is the traditional playing surface in football both for matches and training at the professional level. However, many regions of the world suffer from climatic conditions that limit natural grass growth throughout all seasons. It is therefore difficult to maintain adequate natural grass pitches both in cold and wet climate zones in the northern hemisphere and in dry areas around the Equator. Artificial turfs have inherent advantages such as longer playing hours, lower maintenance costs, better resilience to tough climatic conditions, and multi-purpose application

(FIFA, 2009). Consequently, some national football associations, including the Norwegian, recommend artificial turf for new football pitches. Artificial turf is becoming a common playing turf not only among youth but also in professional football.

Since its introduction in the 1970s, artificial turf has been developed and refined continuously. The first and second generations of artificial turfs had excessive hardness and shoe-surface traction as two main factors contributing to surface-related injuries (Nigg and Yeadon, 1987). Indeed, data from the 1980s and 1990s indicate that the risk of injury on first and second generations of artificial turf was higher than on natural grass (Engebretsen and Kase, 1987; Arnason et al., 1996). These findings, as well as playing characteristics deviating from natural grass, spurred the development of a third generation of artificial turf, consisting of long grass-like fibers with sand and rubber particles in between. Third generation artificial turf (3GAT) was formally recognized in the Laws of the Game in 2004 (FIFA, 2009). With adjusted hardness and traction, the playing characteristics and movement patterns on the new artificial turfs better resembled those on grass (Andersson et al., 2008). However, concerns have been raised that the injury risk of playing on third-generation artificial turf may still be higher compared with playing on grass.

In 2006, Ekstrand and co-workers published the first study looking at injury risk on artificial turf in male professional football. They found no major differences in injury risk between artificial turf and natural grass except, surprisingly, a higher incidence of ankle sprains on artificial turf (Ekstrand et al., 2006). Studies in college and youth football have revealed a similar risk of injury on natural grass compared to artificial turf (Fuller et al., 2007b; Fuller et al., 2007a; Steffen et al., 2007; Soligard et al., 2012), while Steffen and co-workers (2007) found a higher risk of severe match injuries on artificial turf. However, some of these studies included exposure to football on second generation artificial turf. Therefore, in Paper III, we evaluated the risk of injury solely on third generation artificial turf in Norwegian male professional football, compared to the risk of injury on natural grass.

Injury mechanisms

It has previously been argued that sports injury surveillance systems cannot contribute to the identification of the injury mechanism (van Mechelen, 1997). This was supported by Krosshaug et al. (2005), who emphasized the lack of universally accepted definitions for contact and non-contact injuries. In addition, medical staff reports and player interviews are vulnerable to recall bias, and injuries commonly occur in complex settings, where the speed is high and several players are involved (Krosshaug et al., 2005). Most studies on injury mechanisms in football have been based pm information provided by medical staff. These have reported tackling and collisions as the most frequent injury mechanisms in male adult football, followed by running/sprinting and shooting (Inklaar, 1994b; Dvorak and Junge, 2000; Arnason et al., 1996)

The injury mechanisms in football are naturally separated into contact and non-contact injuries, with player-to-player contact responsible for between 44% and 59% of all acute match injuries at the club level (Ekstrand and Gillquist, 1983; Arnason et al., 1996; Hägglund et al., 2005b; Ekstrand et al., 2011c). The corresponding figure seems to be higher during international tournaments (i.e. World Cup, European Championship and Olympic Games), where it has been reported that between 65% and 91% of all match injuries are the result of player-to-player contact (Junge et al., 2004b; Dvorak et al., 2011). The proportion of injuries due to player-to-player contact is higher during match play than football training; this could possibly be explained by the higher intensity in matches.

Another approach to describing the inciting event for football injuries is video analysis, especially when describing the playing situation and athlete/opponent movement and behavior (Krosshaug et al., 2005). The quality of video recordings has traditionally been a limitation; however, in recent years the image quality, the number of camera views available and the resolution have improved tremendously. Another limitation, which must be kept in mind when interpreting the results, is that only about half of all injuries in football matches are identified on video (Arnason et al., 2004b; Andersen et al., 2004d). It should also be noted that the capture rate of injuries varies with injury type, with all head injuries captured, about half of ankle and knee injuries, while only one third of hamstring strains were captured using video analysis (Andersen et al., 2004d).

In a small study of 10 games in the English Premier League during the 1999-2000 season it was documented that the highest risk of injury was when challenging for ball possession, with a higher risk during the first and last fifteen minutes of the match (Rahnama et al., 2002).

A study of the mechanisms of foot and ankle injuries, where video of the injury was available for 76 (67%) of 114 situations, showed that 95% of the ankle and foot injuries were due to player-to-player contact (Giza et al., 2003). However, as a substantial number of injuries were not available for video analysis, the proportion of non-contact ankle and foot injuries was probably underestimated. The majority of the injuries occurred to the weight-bearing limb, and due to tackles involving lateral and medial forces that created corresponding eversion and inversion rotation of the foot (Giza et al., 2003; Fuller et al., 2004c; Andersen et al., 2004c). It is also stated that significantly more injuries occurred from tackles where the tackling player stayed on his feet during the tackle.

The most common cause of head injuries and high-risk head situations are head-to-upper extremity contact, followed by head-to-head contact (Fuller et al., 2004c; Andersen et al., 2004d). In contrast, a study from English football found that elbow use was the injury mechanism in only 1% of the match injuries (Hawkins et al., 2001). Andersen et al. (2004d) found that most incidents with a high risk of head injury occurred during heading duels. Despite of the arm often being used actively in the heading duel, a foul was called in less than one third of the incidents. Fuller et al. (2004) found through video analysis that referees identified only 40% of head/neck injuries as foul play during FIFA tournaments. It has therefore been suggested that awareness about the injury potential of arm-to-head incidents is lacking among referees (Fuller et al., 2004a).

Arnason et al. (2004b) observed that the exposed players in incidents with high risk of injury appeared to have their focus away from the opponent that challenged him for ball possession in 93% of the cases. In another study of high-risk injury situations and injuries in Norwegian football, the exposed player appeared to have his attention directly towards his primary duelist in only 2% of all incidents and in none of the injuries recorded on video (Andersen et al., 2004d). Video analysis of European international matches and English professional matches has shown that significantly more free kicks were awarded during international matches (Hawkins and Fuller, 1998). In the same study, it was shown that despite only 15-28% of all injuries resulting from foul play, most injuries were due to player-to-player contact. The mechanisms of player-to-player contact in the non-foul situations were found to be tackling duels, heading duels and unintentional collisions (Hawkins and Fuller, 1998).

However, no studies have evaluated the characteristics and changes of player-to-player contact and situation with a propensity for injury over time. We therefore wanted to compare the rate of incidents, situations with a propensity for injury, from the 2000 season to the 2010 season. In addition, we wanted to compare the rate and characteristics of duels between the two seasons. These issues were addressed in Paper IV.

Injury prevention in football

With the high injury incidence and serious consequences of injury in football, injury prevention is essential. The vast majority of research in the field of football medicine has been descriptive epidemiological studies and risk factor studies. A literature search on PubMed using the following search term "prevent*" and (injury OR injuries) and (football OR soccer), revealed 219 studies. The reference lists of retrieved articles were checked manually for potentially relevant studies. A total of 14 studies were found when the search was narrowed to injury preventive studies in senior male football. The studies ranged from the use of orthoses, eccentric strength training, balance training, video-based awareness to multi-modal exercise programs. Of these 14 studies, 10 have demonstrated a reduction of injury incidence in the intervention group. Table 4 summarizes the injury prevention studies in male football.

In 1981, Ekstrand and co-workers conducted the first published randomized controlled trial on injury prevention in football (Ekstrand et al., 1983). The intervention group was introduced to a seven-component program. The risk of injury was reduced by 75% in the intervention group compared to the control group. In addition, there was a significant reduction in the risk of muscle strains, as well as of ankle and knee sprains. The major limitation of this study is the implementation of seven different preventive measures, making it difficult to assess the individual contribution of the each of these features.

After this, Tropp and co-workers (1985) assessed the effect of balance training and use of orthoses on ankle sprains. A total number of 439 players were allocated to three groups; a control group, an orthosis group and a balance training group (ankle disk). The authors found that both ankle disk training and the use of orthoses reduced the incidence of ankle sprains among players with previous ankle sprains. In a similar study, Surve et al. (1994) evaluated the effect of a semi-rigid ankle orthosis on ankle sprains. The players were divided into two groups: players with previous ankle injury and players without previous ankle injury. The two groups were then randomly allocated to an intervention group (using semi-rigid orthosis) or control group. The main finding was that players with a previous history of ankle sprains reduced their risk of a new ankle injury by 60% using orthoses. They found no significant effect on the risk of ankle sprains in previously uninjured ankles. In a study from Iran, no reduction in ankle sprains was seen among players with a history of ankle sprain when using Sport-Stirrup orthosis or a strength training program for the evertor muscles (Mohammadi, 2007). However, a proprioceptive training program using an ankle disk 30 minutes a day resulted in a significantly lower risk of new ankle injuries.

Caraffa et al. (1996) evaluated the effect of gradually increasing proprioceptive training on four different types of wobble-boards on the risk of ACL injuries. The risk of ACL injuries was significantly reduced in the proprioceptive training group.

The rate of hamstring injuries in football is high (table 2); thus, hamstring injuries have been the focus of several prevention studies. In a study from Askling et al. (2003), the intervention group was assigned to specific hamstring training with eccentric overload using a YoYo flywheel ergometer during the preseason. They found that 70% fewer players in the intervention group sustained a hamstring injury during the following season. The training group also showed a significant increase in muscle strength and speed. Later, Mjølsnes et al. (2004) found that a 10-week training program with Nordic Hamstrings (eccentric training) was more effective in increasing eccentric hamstring strength, the hamstrings/quadriceps strength ratio and isometric hamstring strength, than traditional hamstring curl training (concentric training). The authors therefore suggested that performing Nordic Hamstring regularly might prevent injuries. This was later confirmed by Arnason et al. (2008) who found that the incidence of hamstring injuries was lower in teams who used Nordic hamstring combined with warm-up stretching. No difference was found when performing flexibility training alone (Arnason et al., 2008). This was recently supported by a RCT in Danish football that reported a lower rate of overall, new and recurrent acute hamstring injuries after a 10-week progressive eccentric training program during the midseason break followed by a weekly program during the competitive season (Petersen et al., 2011).

Hölmich and co-workers (2010) implemented a similar approach to reduce the risk of groin injuries among male football players. The RCT included 1211 players, where the intervention program included six exercises; strength training (concentric and eccentric), core stability, stretching and coordination. However, no significant effect of the intervention program was detected.

A Norwegian study by Engebretsen et al. (2008) aimed to identify amateur players with an increased risk of injury based on injury history and reduced function through a questionnaire. The players identified as having a high risk of injury were randomized to an intervention group or a control group. The players in the intervention group were provided with an exercise program based on their injury history and asked to complete it three times a week for 10 weeks during preseason. The screening was able to identify the players with an increased risk of injury through the questionnaire; however, they found no effect of the intervention program on the risk of injury (Engebretsen et al., 2008). It should be noted though, that compliance was low, with less than 30% of the players at risk completing their prescribed training programs.

Table 4. Summary of the study population, methods and results of injury prevention studies in male football

Reference	Level of play	N	Injury definition	Study design	Preventive measure	Outcome measure	Main finding
Ekstrand et al. (1983)	Amateur	180	Time-loss (>1 week)	RCT	7-modul program	Overall injury incidence	75% reduction of injuries in the intervention group
Tropp et al. (1985)	Amateur	439	Time-loss (≥1 day)	RCT	Orthosis & balance training	Ankle injury incidence	Reduced risk of ankle sprains in both the orthosis and training group.
Surve et al. (1994)	Amateur	504	Time-loss (≥1 day, missing next match)	RCT	Orthosis	Ankle injury incidence	60 % lower risk of ankle re-injury in the orthosis group
Caraffa et al. (1996)	Amateur	600	ACL injuries (arthroscopy)	Prospective cohort study	Balance training	ACL injury incidence	87% lower risk of ACL injuries in training group
Askling et al. (2003)	Elite	30	Time-loss (≥1 day)	RCT	Eccentric training in special device	Hamstring injury incidence	70% fewer players in intervention group sustained a hamstring injury
Arnason et al. (2005)	Elite	271	Time-loss (≥1 day)	RCT	Video-based awareness program	Overall injury incidence	No difference in injury risk
Hägglund et al. (2007)	Amateur	582	Time-loss (≥1 day)	RCT	Coach-controlled rehabilitation program	Re-injury incidence	Reduction in injury risk in the intervention group.
Mohammadi et al. (2007)	Elite	80	Physical complaint	RCT	1. Proprioceptive training 2. Strength training 3. Orthosis	Incidence of recurrent ankle sprains	78% reduction of recurrent ankle sprains after proprioceptive training
Fredberg et al. (2008)	Elite	209	Physical complaint	RCT	Eccentric training and stretching of patellar and Achilles tendon	Achilles and patellar tendinopathy	No difference in injury risk between the intervention and control group
Arnason et al. (2008)	Elite	NA	Time-loss (≥1 day)	Prospective cohort study	Eccentric training (Nordic hamstring lowers) Flexibility training	Hamstring injury	Reduced risk of hamstring injuries in the Nordic Hamstring group. No difference in the flexibility group
Croisier et al. (2008)	Professional	462	Severe injuries/MRI/US/PE	Prospective cohort study	Strength training	Hamstring injury incidence	Reduced risk of hamstring injuries in the group that normalized isokinetic parameters
Engebretsen et al. (2008)	Amateur	525	Time-loss (≥1 day) Non time-loss for groin and hamstring	RCT	Neuromuscular training Nordic hamstring Groin strength training	Lower extremity injury incidence	No difference in injury risk
Hölmlich et al. (2009)	Amateur	977	Medical attention	RCT	Six exercises (strength, stretch)	Groin injury incidence	No difference in injury risk
Petersen et al. (2011)	Amateur & professional	942	Physical complaint	RCT	Eccentric training	Hamstring injury incidence	Reduced rate of overall, new and recurrent acute hamstring injuries

Fredberg et al. (2002) have shown that asymptomatic soccer players with an increased risk of developing patellar and Achilles tendon injuries within the next 12 months can be identified by ultrasonography. The study group initiated an RCT in order to prevent the occurrence of tendon injury among players with asymptomatic tendon changes. Twelve teams were randomized to take part in the intervention or the control group. The intervention program consisted of eccentric training and stretching of both the patellar and Achilles tendon three times weekly. In contrast to the hypothesis, players with asymptomatic ultrasonographically abnormal patellar tendons who were assigned to the extra training in the intervention group had an increased risk of injury. Players in the intervention group with normal ultrasonography had a significantly lower risk of developing ultrasonographically abnormalities, but the intervention program had no effect on the risk of injury.

After studying situations with a propensity for injury in Icelandic football, Arnason et al. (2005) wanted to test the effect of a video-based awareness program on the incidence of acute injuries. Teams from the top two divisions in Icelandic football were randomized to an intervention group and a control group. The intervention teams were visited prior to the league start and given information on the risk of injury, typical injuries and their mechanism. However, no significant differences in the risk of injury between the intervention and control group were detected.

Most injury prevention studies have been aimed at the players and different training regimens; thus, Hägglund et al. (2007) changed the focus to the coaches. Their intervention was implemented by team coaches, and consisted of information about risk factors for re-injury, rehabilitation principles and a 10-step progressive rehabilitation program including return-to-play criteria. The controlled rehabilitation program resulted in a 66% reduction of re-injuries in the intervention group for all injuries and 75% reduction for lower limb injuries. In addition, the compliance with the rehabilitation program was high; 68% of the players followed the recommended number of training sessions before return to play.

The proportion of acute match injuries due to player-to-player contact is high; therefore, reduction of foul play has been proposed as a possible intervention to reduce injury rates in football (Dvorak et al., 2000). A German study showed that coaches can positively influence both the understanding of fairness and fairness behavior of young footballers. Thus, they emphasized that coaches should be challenged to serve as role models, by exemplifying fair play by their own actions (Pilz, 2005). In addition, White et al. (2013) showed that coaches are receptive to implementation of injury preventive measures, and suggested that prominent coaches can serve as role models for community-level coaches.

An editorial highlighted that the effects of rules and regulations on injury risk is a key element missing from sports injury prevention research (Matheson et al., 2010). In American football "spearing" was banned in 1976, leading to a significant reduction of catastrophic cervical spine injuries (Heck et al., 2004). In a youth ice hockey tournament, the risk of injury was 4.8 times higher when regular rules were applied compared to "fair play" rules (points for playing without excessive penalties) (Roberts et al., 1996). Video analyses have shown that referees identify only 40% of head/neck injuries as foul play during FIFA tournaments (Fuller et al., 2004a). It has therefore been suggested that knowledge regarding the injury potential of arm-to-head incidents is lacking among referees. As a consequence, the International Football Association Board gave referees the authority to sanction potentially injurious fouls, such as intentional elbows to the head, with automatic red card (Dvorak et al., 2007). After this, the incidence of match injuries was significantly lower in the 2010 FIFA World Cup for men compared to the mean incidence found in the three previous World Cups (Dvorak et al., 2011). This was partly explained by stricter rule enforcement. However, the effect of rule changes and a stricter interpretation and enforcement of the Laws of the Game have neither been evaluated through prospective injury surveillance systems nor using systematic video analyses. No previous prospective studies have evaluated the effects of rule changes on the risk of injury in football

We therefore wanted to assess whether stricter interpretation of the Laws of the Game could reduce the potential for injuries in Norwegian male professional football. This is addressed in Paper V.

Aims of the thesis

The general aim of this thesis was to reduce the risk of injuries in Norwegian professional football. A continuous injury registration system was established in 2000 to reveal the extent of the injury problem and the causes of injury, in order to develop and introduce injury preventive measures.

The specific aims of this thesis were:

I. To assess the accuracy of a prospective injury registration system based on medical staff reporting by comparing it to retrospective player interviews (Paper I).

II. To monitor changes in the incidence of injury and injury pattern in Norwegian male professional football over seven seasons (Paper II)

III. To evaluate if there was an increased risk of injury during the preseason compared to the competitive season (Paper II).

IV. To compare the risk of acute injuries on natural grass to third-generation artificial turf in male professional football (Paper III).

V. To compare the incidence of situations with a propensity for injury during the 2000 season to the 2010 season in Norwegian male professional football, with a particular focus on tackling characteristics (Paper IV).

VI. To assess whether more strict interpretation of the Laws of the Game could reduce the potential for injuries in Norwegian male professional football (Paper V).

Methods

Study population (Paper I-V)

This thesis is based on a prospective injury surveillance system in the male Norwegian professional football league (Tippeligaen), established by the Oslo Sports Trauma Research Center in 2000 (Andersen et al., 2004d). Its main objective is to survey injury incidence and injury trends over time. We invited all players with a first-team contract to participate in the study, but did not include players on trial or youth players without a professional contract. Paper I includes information from July through October 2007, paper II includes data from 2002 through 2007, paper III includes data from 2004 through 2007, and paper V includes the 2010 and 2011 seasons.

Validation of injury registration (Paper I)

Study design

Paper I is a methodological study comparing two different injury recording methods during three months of the 2007 season. The first method was the prospective injury registration, where the medical staff of each club was asked to record all injuries sustained throughout the season (January – November) by players with a first team contract. The second registration method was retrospective interviews with the players in October about all injuries sustained during three of the four final months that season (i.e. from July through September). The team medical staff was kept unaware of the player interview sessions we planned to do toward the end of the season.

Player interviews

Physicians and medical students from OSTRC completed one-on-one interviews based on a structured interview form that was first developed for volleyball (Bahr and Reeser, 2003) and later also used in World Cup skiing (Flørenes et al., 2011). To facilitate player recall, the interviews were based on a week-by-week schedule of each club's training and match program for the three-month study period. The interviewers were blinded to the data from the prospective injury registration. Player interviews were conducted in quiet and private surroundings. Telephone interviews were carried out with players not present during the team interview sessions. The players were asked if they participated fully in first team training and were available for match selection each week. They were also asked whether or not they were selected for the match squad that week. If they did not participate fully in training or were not selected in the match squad, we asked if they had an injury during that period. If a player reported an injury, we informed him about how we defined an injury and asked when he was able to participate fully in football training. We completed the same injury registration form as used by the medical staff registration. In addition, match previews by the largest newspapers, the homepage of each club and local newspapers were monitored to double check information gained through both player interviews and medical staff registration. We also checked that players claiming to be injured did not appear on the match roster during the period in question.

Injury registration and definitions (Paper I, II, III, V)

A member of the club medical staff, in most cases the physiotherapist, performed the prospective injury registration. The club license in Norway requires that a physiotherapist attends each football activity, training and match throughout the season. We used a time-loss definition, in accordance with the consensus statement, when recording injuries; an injury was registered if the player was unable to take a full part in football activity or match play at least one day beyond the day of injury (Fuller et al., 2006). The player was considered injured until declared fit for full participation in training and available for match selection by the medical staff (Fuller et al., 2006).

According to the onset of an injury, injuries were defined as acute or overuse, evaluated by the medical staff. If the injury was the result of a specific, identifiable event, it was defined as acute. If the onset was gradual, without a single, identifiable event, it was reported as an overuse injury (Fuller et al., 2006). Overuse injuries were not included in Paper III, as they could not be attributed to a specific training session or match (and hence, turf type).

The injury form included information about the date of injury, the type of activity (match or training) in which the injury occurred, injury location and injury history.

The injury surveillance system was implemented prior to the consensus statement, thus the severity categories used in Paper II and III differ from the consensus statement. In Paper II and III we based the classification of injuries on the NAIRS; injuries were categorized according to the duration of absence from match and training sessions as: mild (1-7 days), moderate (8-21 days) and severe (>21 days) (van Mechelen et al., 1992). Papers I and V were completed after the consensus statement; therefore, injuries were categorized into four severities, according to the consensus statement: minimal (1-3 days); mild (4-7 days), moderate (8-28 days) and severe (>28 days) (Fuller et al., 2006).

Prior to the 2010 season, the methodology of the UEFA injury study was implemented, leading to some minor modifications in the injury registration method. Injury severity was categorized according to the consensus statement and the injury card included information on injury mechanism and the referee's sanction.

Forms were collected on a monthly basis and, if needed, we followed up with reminder text messages and phone calls. We checked the injury cards thoroughly when we received them. If information was missing or any other inconsistencies were seen, a member of the study group contacted the medical staff to resolve these.

Exposure registration (Paper II, III and V)

We collected exposure data on a separate form asking for information about the type and duration of match or training, the number of participants and the surface during the particular training or match (Paper II and III). Match exposure for players included all matches between teams from different clubs of players with an A-squad contract. Training exposure was defined as any physical activity carried out under the guidance of a member of the first teams coaching staff. A member of the coaching staff or the medical staff completed the exposure form.

After the implementation of the methodology from the UEFA injury study, exposure registration was altered from the team level to the individual level (Paper V). Individual player exposure to activity in training and matches was registered by the clubs on a standard exposure form in Microsoft Excel. We also included national team exposure.

Video analysis (Paper IV and V)

We collected videotapes prospectively throughout the 2000, 2010 and 2011 seasons to be reviewed by the study group. An *incident* was said to have occurred if the match was interrupted by the referee, the player stayed down for more than 15 s, and appeared to be in pain or received medical treatment. We did not include incidents caused by muscle cramps. Each incident was classified according to predetermined criteria: the cause (opponent-player contact, teammate-player contact, ball-player contact or non-contact) and body location involved. A duel was defined as a situation where two opponents challenged each other for ball possession; duels were classified as heading duel, tackling duel or other duel (screening or running). We also categorized the referee's decision (no foul, foul for, foul against) and the referee's sanction (no sanction, yellow card or red card). In addition, incidents affecting the head were classified by cause (head-to-head, arm-to-head, trunk-to-head, leg-to-head, in addition head-to-ground/ball/object were listed as head-to-other).

We also analyzed all tackling incidents using variables utilized for video analyses of injuries from three FIFA tournaments (Fuller et al., 2004c). The following variables were included: the direction of the tackle (tackling player approached from the front, the side or from behind the tackled player), action during tackle (one-footed tackle, two-footed tackle, use of arm/hand, upper body contact, clash of heads) and tackling mode (tackling player staying on feet, sliding in or jumping vertically). In addition, the study group assessed whether the tackle was late (the tackle occurred after the ball had been passed by the tackled player) and whether the tackling player made contact with the ball (prior or after initial contact with the tackled player) or not (Andersen et al., 2004c). We also classified the tackling incidents in two categories. If the tackled player also tackled, it was indexed as an active tackling duel. However, if the tackled player was tackled by an opponent it was indexed as a passive tackling duel.

In 2000, the league was a double round robin competition with home and away matches between 14 teams, resulting in a total of 182 matches. Of these, 174 (96%) were available on video. Of the 174 videotapes, 157 covered the full match, while the remaining 17 covered 73 minutes on average (range: 36-87 min). The total duration of the video recordings was 15 367 minutes; thus, we were able to analyze 256 hours (94%) of a total of 273 hours of football matches in the 2000 season. The 256 hours of match play corresponded to a total of 5 632 player hours. In 2010 and 2010, 16 teams participated in the Norwegian male professional league. All of the 240 matches were available on video, corresponding to 360 hours of match play and 7 920 player hours.

In addition, we conducted a video analysis of all player-to-player contact situations occurring during match play. We randomly selected 14 matches from the 2000 season and 16 from the 2010 and 2011 season (one home match and one away match for every team). We registered the type of duel (tackling, heading and other). For heading duels we included the contact between the two opponent players (trunk-trunk, head-head, arm-head, foot-head).

Stricter rule enforcement (Paper V)

During the fall of 2010 the Football Association of Norway (NFF) and the Norwegian Professional League Association (NTF) met with the project group from the Oslo Sports Trauma Research Center (OSTRC) and members of FIFA-Medical Assessment and Research Centre (F-MARC) to discuss the implementation of stricter rule enforcement in 2011 in the Norwegian male professional league (Tippeligaen).

Video recordings of situations with a propensity for injury and injuries from the 2010 season were analyzed and refereeing guidelines were agreed upon according to FIFA regulations. This involved sanctioning of two-foot tackles as well as tackles with excessive force and intentional high elbow with an automatic red card. A total of 15 referees and 25 assistant referees were familiarized with the stricter rule enforcement in meetings at the end of 2010 and in a training camp in January 2011.

The plans for stricter rule enforcement were introduced to each of the teams in meetings with referees appointed for the 2011 season. During these one-hour meetings the stricter interpretation of the rules was introduced through video clips, lectures and discussions. After informing the players, the study group and the Head of Refereeing in the Football Association of Norway held a similar meeting for the media. We also organized a press conference which included a high-profile player, manager and FIFA representative a week prior to the start of the season to inform the public.

Outcome measures

The primary outcome measure was the overall rate of contact incidents before and after the introduction of stricter rule enforcement in the 2011 season. Secondary outcome measures were the rate of head contact incidents, ankle contact incidents and contact injuries. Our hypothesis was that stricter rule enforcement by the referees would lead to a reduction in the number of incidents, especially head and ankle incidents.

Statistical methods

Most of the analyses were executed using the Statistical Package for Social Sciences (SPSS) (SPSS for Windows 15.0, SPSS Inc, Chicago, III.).

In Paper I, Kappa ($\varkappa$) correlation coefficients were calculated for agreement between methods (Altman, 1991). Coefficients of 0.81 to 1.00 are generally interpreted as very good, 0.61 to 0.80 as good, 0.41 to 0.60 as moderate, 0.21 to 0.40 as fair, and less than 0.20 as poor (Altman, 1991).

In Paper II, III and V results are presented as injury incidence (injuries/1 000 hours of exposure) in training and match play. The same method was applied for the analysis of incidents with a high risk of injury with the number of incidents as the numerator. We used a z test and the 95% confidence interval (CI) based on the Poisson model to compare the rate ratio between preseason and the competitive season (Paper II) and natural grass and artificial turf (Paper III), the 2000 season and the 2010 season (Paper IV) the 2010 season and the 2011 season (Paper V).

Correspondingly, the rate ratios (RR) are presented with competitive season, natural grass, the 2000 season and the 2010 season as the reference group. A two-tailed p-value≤0.05 was regarded as significant.

In Paper II, we estimated changes in injury incidence over the study period using linear regression, were the injury incidence was the dependent variable and year as the independent variable. In addition, we used a general estimating equation (GEE) model approach with teams as clustering factor and correlation structure chosen as exchangeable to evaluate changes in injury incidence. A robust estimation method was undertaken. Linear regression and GEE were done in STATA 12. In Paper II, IV and V categorical variables were compared with the χ^2 test.

In Paper III, with natural grass as the reference group we adjusted for the correlation between the dichotomy match/training and both injury and artificial turf/natural grass. Overall injury incidence on natural grass/artificial turf was calculated using a stratified analysis by match/training. The pooled estimate natural grass/artificial turf across the strata (match/training) was made by a weighted average using the reciprocal of the variances of the rates as weights.

Sample Size (Paper V)

We calculated our sample size using a formula for cohort studies with Poisson outcomes (Gail and Benichou, 2000) based on incident rates in the 2000 season, i.e. 75 incidents per 1000 player-match hours (Andersen et al., 2004d). An estimated total of 630 incidents per season would provide an acceptable power of 0.9 at the 5% significant level to detect a 30% reduction in the number of incidents. Correspondingly, an estimate of 180 ankle and head incidents per season would enable us to detect an effect size of 50% for these two categories. Based on an expected incidence of 18 acute injuries per 1000 player-match hours, with 13 participating clubs and assuming that approximately 50% of all injuries would be contact injuries, we expected a total of 50 recorded match contact injuries each season. Thus, we would need a decrease in contact injury incidence of 70% after the introduction of stricter rule enforcement in Norwegian professional football to have a power of 0.9 and a 5% significance level.

Ethics

The studies were approved by the Regional Committee for Medical Research Ethics, Region Øst-Norge and the Norwegian Social Science Data Services. The players received written and oral information about the study, it was emphasized that participation was voluntary. All data collected was treated confidentially.

Results and discussion

Validation of injury registration in Norwegian professional football (Paper I)

During the 2007 season, all 14 clubs in Tippeligaen agreed to participate in the methodological study with both medical registration and player interviews. However, one club was excluded from this study because the medical staff had not provided any information prior to the player interviews. Of 310 eligible players, 296 (95%) were interviewed and included in the study. During the three-month study period, 133 (45%) of the players sustained at least one injury and a total of 174 unique injuries were registered.

We found that medical staff reports underestimated the incidence of time-loss injuries by 19% for the 3-month study period as a whole (Table 5). The study also showed that 30% of the injuries registered by the medical staff were not reported by the players, indicating that there is a significant recall bias associated with retrospective player interviews.

Table 5. Comparison of injuries recorded through medical staff reports, player interviews or both methods.

	Medical staff	Both methods	Player interview
All injuries	52	89	33
July	16	18	4
August	21	28	11
September	15	43	18
Acute injuries	34	66	23
Overuse injuries	18	23	10

For the 89 injuries recorded through both methods, the $\varkappa$-correlation coefficients for agreement between the medical staff report vs. the player interviews were 0.61 (95% CI 0.48 to 0.74) for injury severity, 0.97 (0.92 to 1.01) for injury type, 0.99 (0.96 to 1.01) for body part injured and 0.89 (0.79 to 0.98) for activity when injured. Of the 33 injuries not recorded by the medical staff, 76 % were minimal or mild (absence < 1 week). Surprisingly, one severe injury was not registered by the medical staff. Of the 52 injuries only reported by team medical staff, 74% lead to absence less than one week. All severe injuries were detected through player interviews.

Injury surveillance

That more injuries are recorded by prospective injury registration compared to retrospective interviews is in accordance with previous studies from football, among preschool children and physical education students (Junge and Dvorak, 2000; Twellaar et al., 1996; Fonseca et al., 2002). In a study by Junge & Dvorak (2000), Czech football clubs were followed on a weekly basis by a physiotherapist to record injuries, after 12-months the players filled out a questionnaire to recall all injuries sustained during the 12-month study period. They found that there is a significant recall bias associated with retrospective player interviews, especially mild injuries sustained one year in the past (Junge and Dvorak, 2000). We tried to minimize the effect of recall bias by limiting the study period to three months, as well as by using a week-by-week schedule of each club's training and match program and asking the players whether they were selected for the match squad or not, and whether they played the match. Nevertheless, player recall appeared to deteriorate month by month. Of injuries occurring during July, 42% were only recorded by the medical staff. For August and September the proportions were 35% and 20%, respectively.

Interestingly, medical staff recording is not necessarily the best injury registration method in all settings. A recent study among elite skiers and snowboarders found that only 61% of all recorded injuries were reported by the medical staff, and that only 6% of the injuries identified were missed by retrospective player interviews (Flørenes et al., 2011). However, in winter sports the teams and athletes travel continuously during the competitive season, thus, injury registration on a regular basis might be difficult for team medical staff. In contrast, football teams spend most of the week in their own training facilities, with team medical staff in attendance most of the time.

Nilstad et al. (2012) compared individual self-reported registration through text messaging to routine medical staff registration in female elite football in Norway. All players received three text messages each week with questions regarding football activity and whether they had sustained an injury. When an injury was reported, the player was contacted by the study group to complete an injury form. Surprisingly, the medical staff missed approximately 2/3 of all injuries, and 50% of all severe injuries (Nilstad et al., 2012). However, the medical staff was not blinded to the athlete registration, and this may have contributed to the low capture rate by the medical staff. In addition, the resources in female football are considerable lower than male football, and team medical staff do not attend training on a day-to-day basis.

Thus, injury registration systems should be tailored, not only to the sport but also the population they are intended for, using different methods in different sports and level of play, depending on the availability of medical staff.

Injury registration in the future

Professional football players are employees, and therefore covered by the same health and safety legislation as other workers (Fuller, 1995). Injury surveillance is a key risk management tool, to monitor injury incidence and injury patterns to ensure the safest possible work environment for the players. Today, injury registration is not compulsory for the clubs and their medical staff. Implementation of injury registration as a requirement to be issued a club license by the national football association would ensure that this important risk management tool is in place.

The accuracy of an injury surveillance system is the responsibility of the study group; it is therefore important to establish routines for ongoing education of the medical staff involved, regular feedback with injury statistics and close follow-up. In the European Championships and FIFA tournaments the medical staff is contacted every third day and after each match, respectively (Walden et al., 2007; Junge et al., 2004a). In addition, the registration of exposure on the individual level allows both the study group and medical staff to verify absences and injury reports. Another possibility is media monitoring; Faude et al. (2006) concluded that media-based injury statistics were almost complete; but the specific diagnosis were not available in all cases. With the technological development over the last decades, web-based injury surveillance system could be the solution to secure the quality of injury registration. This will enable the injury surveillance component to be linked to the player's medical record, and even team schedule and roster. Computer-based systems could be programmed to flag discrepancies automatically. However, it must be underlined that such an surveillance system must take into account the need for strict player confidentiality (Hägglund et al., 2005a). A significant proportion of overuse injuries do not lead to time loss from sports participation; players often continue training and playing matches even when limited by pain and reduced function. Thus, overuse injuries are therefore underestimated in most injury surveillance studies (Bahr, 2009). Based on these observations, Clarsen et al. (2012) developed and validated a new overuse injury questionnaire, where the athletes on a weekly basis registered problems that were suffered. They found that of 419 recorded overuse problems resulting in reduced performance or participation, however, only 142 (34%) resulted in absence from activity. However, no such studies have been conducted in football; thus, the prevalence of playing with pain, reduced function and performance limitations has not been evaluated in football.

The risk of injury in male professional football has been studied extensively, but information regarding the incidence and effects of illness is limited. Recently a couple of reports following one team for several seasons have been published (Orhant et al., 2010; Parry and Drust, 2006).

They have found that the most common causes of absence due to illness are upper respiratory tract problems and gastrointestinal complaints. However, authors concluded that the impact of illness on absence from training and match is minimal, but that the effect on performance is unknown. As noted, these studies have only included one team; thus, there is a need for larger prospective cohort studies including information on illness and problems related to overuse injuries among professional football players.

Change in risk of injury in Norwegian professional football (Paper II)

The aim of Paper II was to monitor injury incidence and pattern over six seasons in Norwegian male professional football. A total of 494 157 player hours of activity were registered during the six-year long study period; 348 521 player hours (70.5%) of football training, 84 503 hours (17.1%) of other training and 61 133 (12.4%) player-match hours. A total of 2 365 injuries were recorded; 1 664 (70.4%) acute injuries and 701 (29.6%) overuse injuries (Table 6).

Table 6. Exposure and injuries over the six-season study period.

Season	2002	2003	2004	2005	2006	2007
No. of teams	12	11	13*	14*	11	12
Exposure (hours)	90 916	80 169	75 421	77 722	80 628	86 284
Football training	67 273	57 555	51 170	55 229	56 134	61 159
Other training	12 058	12 888	13 682	12 097	16 123	17 656
Match	11 586	9726	10 569	10 396	8371	10 486
Injuries (number)	424	422	368	373	332	446
Acute	271	299	248	282	254	310
Football training	115	139	86	106	90	119
Other training	6	10	6	10	6	2
Match	150	150	156	166	158	189
Overuse	153	123	120	91	78	136
Injury incidence						
Acute						
Football training	1.7	2.4	1.7	1.9	1.6	1.9
Other training	0.5	0.8	0.4	0.8	0.4	0.1
Match	12.9	15.4	14.8	16.0	18.9	18.0
Overuse	1.7	1.5	1.6	1.2	1.0	1.5
Acute match injury incidence						
Hip/groin	0.6	1.4	0.6	0.8	1.1	1.3
Thigh	3.2	3.4	2.9	3.2	5.0	4.3
Knee	1.4	2.7	2.9	2.3	3.2	2.6
Lower leg	1.1	1.9	2.3	1.4	1.8	1.9
Ankle	2.9	2.8	1.9	3.1	3.3	3.4

*Three clubs participated with match exposure and acute injuries

Injury incidence

Using the aggregated injury incidence each season as dependent variable in a linear regression model (n=6), the acute match injury incidence showed an increase of 1.06 injuries/1 000 player hours (95% CI: 0.40 to 1.73, p=0.012) (Figure 2) per year. This corresponds to an estimated total increase of 49% over the 6-year observation period. When accounting for interteam variation and clustering effects using a GEE model, the increase in injury incidence was 0.92 injuries/1 000 player hours (95% CI: -0.11 to 1.95, p=0.083). Correspondingly, the aggregated league match injury incidence showed an annual increase of 0.66 injuries/1 000 player hours (95% CI: 0.01 to 1.31, p=0.048), which was not significant when correcting for interteam variation in the GEE model (0.69 injuries/1 000 hours, 95% CI: -0.68 to 2.06, p=0.32). We did not detect any change in the incidence of overuse injuries (p=0.73), nor in acute training injuries (p=0.49) during the six-year study period.

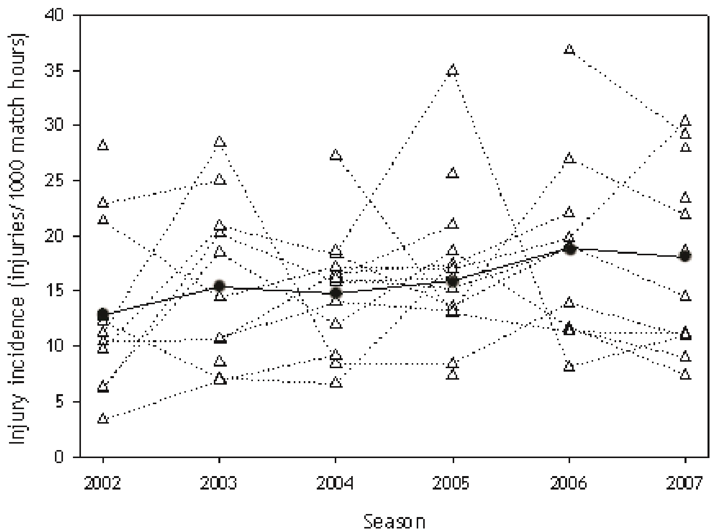

Figure 2. The incidence of acute match injuries for all participating teams over the six-season study period (n=73). The filled circles and solid line depicts the aggregated incidence of acute match injuries.

Has the match injury incidence increased?

The main finding of Paper II was that the overall incidence of acute match injuries increased during the study period; however, using a conservative statistical model correcting for clustering effects showed that interteam variation was substantial. Our results are in contrast to a recent 7-year study from the top European professional level, where no change was seen (Ekstrand et al., 2011c). Notably, we did not find any significant differences in the incidence of acute training injuries or overuse injuries. Due to small numbers we were not able to detect any changes in injury type, location, severity or the proportion of re-injuries during the study period.

While we observed an alarming 49% increase in acute match injury risk during the study period, the results also show that this increase was not fully consistent across teams. This is of course partly due to chance, as the average number of injuries per team per season was no more than 13, assuming an equal distribution between teams. Correcting for variability between teams and clustering effects (that players within teams may be more alike than between teams), as we have done with the GEE model, may therefore represent an overly conservative approach.

The injury incidence of acute match and training injury is still lower in Norwegian male professional football compared to other professional leagues in Europe (Hawkins and Fuller, 1999; Hägglund et al., 2005b; Waldén et al., 2005b; Hägglund et al., 2009; Ekstrand et al., 2011c). In Paper I we showed that medical staff reporting failed to capture about 20% of all time-loss injuries in Norwegian professional football. However, we would expect that there is underreporting in other studies, as well, and even if we underestimated match injury incidence by 20%, it would still be lower than other studies (25.9 to 34.8 injuries/1000 player-match hours) (Hawkins and Fuller, 1999; Hägglund et al., 2005b; Waldén et al., 2005b; Ekstrand et al., 2011c). Waldén et al. (2011a) have categorized teams after the Köppen-Geiger climate classification system and found a higher incidence of severe injuries and training injuries and a lower rate of ACL injuries in Northern parts of Europe, suggesting that there are regional differences in injury incidence in Europa. Our findings show a low rate of ACL injuries in Norwegian football. Also the overall injury incidence and incidence of severe injuries are lower in Norwegian football compared to results from the Champions League.

Why has the match injury incidence increased?

Dupont et al. (2010) followed 32 football players playing in the UEFA Champions league for two seasons to evaluate the effects of playing two matches per week. They found that the recovery time was sufficient to maintain the level of physical performance, but the injury rate was significantly increased when playing two matches per week. However, following one team over 26 days with 8 matches, no difference were detected when comparing to a similar period with fewer matches (Carling et al., 2012). Thus, the effect of match congestion on injury risk needs to be addressed in future studies. During the study period the Norwegian league was a double round robin competition with home and away matches between 14 teams, played from April throughout October, resulting in each team playing a total of 26 league matches, or an average of

3.7 matches per month. In contrast, the English league runs over 9 months (August-May), and consists of 20 teams, giving an average of 4.2 matches per month. In addition, few Norwegian teams participated in European Cups (Champions League and UEFA cup). As the Norwegian league ended late October, many of the European cup games were played "off-season", therefore not increasing the monthly match rate. Thus, players in the Norwegian league play a lower number of games than players at the Champions League level, and other European leagues. Moreover, the number of match hours per club was fairly stable over the study period. A limitation of the Norwegian injury surveillance system is that exposure data is only collected on a team basis, i.e. the total number of players present during each practice. We are therefore not able to test whether the total load (number of games) per player has increased during the study period, nor are we able to examine potential risk factors for the onset of overuse injuries leading to absence from training or match for each player. It has been recommended that exposure is recorded on an individual basis (Fuller et al., 2006).

A report from the Institute for Research in Economics and Business Administration showed that the percentage of foreigners playing professionally in Norway increased gradually from 2000 to 2006 (2000: 15%, 2002: 22%, 2006: 35%) (Gammelsæter and Jacobsen, 2007). It is a possibility that this globalization of the Norwegian league not only has affected the level of play, but also the style of play.

The proportion of match hours on artificial turf was 26% in the 2006 and 2007 season, and if the increased risk seen in match injuries found in Paper II were solely due to the introduction of artificial turf, the injury incidence on artificial turf would have had to be about 33 injuries/1000 player-match hours. In contrast, our data suggest that the match injury incidence was 17.6 (95% CI: 14.7-20.5) on artificial turf (Paper III), thus excluding artificial turf as the explanation for the increased risk of match injuries found in Norwegian professional football.

Injury pattern

About half of all injuries sustained by Norwegian professional players resulted in absence from football activity for one week or less is in accordance with other studies (Ekstrand and Gillquist, 1983; Hägglund et al., 2005b; Ekstrand et al., 2011c). The predominant injury type was muscle injuries (46%), followed by joint injuries (27%) and contusions (14%). Despite finding a lower incidence of match and training injuries, the injury pattern found in our study is in accordance with previous studies at a comparable level of play and we could not detect any substantial changes during the study period. The proportion of re-injuries was approximately 20% of all injuries; this is in accordance with previous studies (Waldén et al., 2005a; Hägglund et al., 2006).

We found that about 30% of all injuries were overuse injuries and that the rate remained constant during the study period. This is in correspondence with previous studies from elite and professional football where the proportion of overuse injuries ranged from 9% to 39% (Waldén et al., 2005b; Arnason et al., 1996; Ekstrand et al., 2011c). Recent studies have showed that standard injury surveillance systems are not suitable for capturing overuse problems as few of the problems recorded led to absence from activity (Clarsen et al., 2010; Clarsen et al., 2012). Thus, the prevalence of overuse injuries is underestimated.

The injury risk during the preseason vs. the competitive season

Previous studies from outside Scandinavia (Hawkins and Fuller, 1999; Ekstrand et al., 2011c) have shown an increased incidence of overuse injuries during the preseason, and a lower incidence of traumatic training injuries during the preseason. In contrast, a Swedish study found an increased incidence of training injuries during the preseason (Waldén et al., 2005a). We were not able to detect any differences in the injury risk between the preseason and the competitive season for acute match injuries (RR: 0.86, 95% CI: 0.73 to 1.01), acute training injuries (RR: 1.16, 95% CI: 0.99 to 1.36) or overuse injuries (RR 1.04 95% CI: 0.89 to 1.21). We found a significantly higher incidence of acute injuries with moderate severity and acute knee injuries during preseason training (Table 7). The incidence of mild acute match injuries was higher during the competitive season.

It must be noted that the league system in Norway and Sweden is different compared to most European leagues. Due to climatic conditions, the Norwegian and Swedish leagues start in April and end in October/November, with a 3 month preseason period starting in January. Most other European leagues have a 4- to 6-week preparation period. Thus, the preseason in other European leagues may be more intense and strenuous, with a correspondingly higher injury incidence. In addition, the coaching, fitness and medical staff in Norway have a longer period to get the players match fit, with the possibility for an increased focus on individual adjustments.

Table 7. Characteristics of injuries sustained during the preseason and competitive season. The incidences are reported per 1000 h of exposure with 95% confidence intervals. Rate ratios between injuries on preseason and competitive season are shown with 95% confidence intervals, with the competitive season as the reference group.

	Pre-season		Competitive season		Preseason vs. competitive season
	Injuries	Incidence	Injuries	Incidence	Rate ratio
Acute match injuries (n=969)					
Injury type					
Fracture	13	1.0 (0.5-1.6)	50	1.0 (0.7-1.3)	0.97 (0.56-1.90)
Muscle and tendon	43	3.3 (2.3-4.3)	234	4.9 (4.2-5.5)	0.69 (0.50-0.95)
Joint and ligament	71	5.5 (4.2-6.8)	246	5.1 (4.5-5.7)	1.08 (0.83-1.40)
Contusions	38	2.9 (2.0-3.9)	187	3.9 (3.3-4.4)	0.76 (0.54-1.08)
Body location					
Groin	6	0.5 (0.1-0.8)	52	1.1 (0.8-1.4)	0.43 (0.19-1.00)
Thigh	45	3.6 (2.5-4.5)	176	3.6 (3.1-4.2)	0.96 (0.76-1.45)
Knee	29	2.2 (1.4-3.1)	122	2.5 (2.1-3.0)	0.88 (0.75-1.69)
Ankle	47	3.6 (2.6-4.7)	130	2.7 (2.2-3.2)	1.35 (0.97-1.88)
Time loss					
1 to 7 days	77	6.0 (4.6-7.3)	394	8.2 (7.4-9.0)	0.73 (0.57-0.93)*
8 to 21 days	65	5.0 (3.8-6.3)	228	4.7 (4.1-5.3)	1.07 (0.81-1.40)
>21 days	39	3.4 (2.1-4.0)	166	3.4 (2.9-4.0)	0.88 (0.62-1.24)
Acute training injuries (n=655)					
Injury type					
Fracture	10	0.1 (0.0-01)	23	0.1 (0.1-0.1)	0.89 (0.42-1.86)
Muscle and tendon	90	0.8 (0.6-0.9)	160	0.7 (0.6-0.8)	1.15 (0.89-1.48)
Joint and ligament	87	0.8 (0.6-0.9)	161	0.7 (0.6-0.8)	1.10 (0.85-1.43)
Contusions	37	0.3 (0.2-0.4)	57	0.2 (0.2-0.3)	1.32 (0.88-2.00)
Body location					
Groin	16	0.1 (0.1-0.2)	28	0.1 (0.1-0.2)	1.17 (0.63-2.15)
Thigh	63	0.5 (0.4-0.7)	117	0.5 (0.4-0.6)	1.10 (0.81-1.49)
Knee	49	0.4 (0.3-0.5)	68	0.3 (0.2-0.4)	1.47 (1.02-2.12)*
Ankle	40	0.3 (0.2-0.5)	84	0.4 (0.3-0.4)	0.97 (0.66-1.41)
Time loss					
1 to 7 days	102	0.9 (0.7-1.1)	232	1.0 (0.9-1.1)	0.89 (0.71-1.13)
8 to 21 days	80	0.7 (0.5-0.9)	101	0.4 (0.3-0.5)	1.61 (1.20-2.17)*
>21 days	56	0.5 (0.4-0.6)	84	0.4 (0.3-0.4)	1.36 (0.97-1.91)
Overuse injuries (n=701)					
Injury type					
Muscle and tendon	190	1.1 (1.0-1.3)	340	1.0 (0.9-1.2)	1.09 (0.91-1.30)
Joint and ligament	15	0.1 (0.0-0.1)	51	0.2 (0.1-0.2)	0.57 (0.32-1.02)
Body location					
Groin	59	0.4 (0.3-0.4)	94	0.3 (0.2-0.3)	1.22 (0.88-1.69)
Thigh	34	0.2 (0.1-0.3)	71	0.2 (0.2-0.3)	0.93 (0.62-1.40)
Knee	40	0.2 (0.2-0.3)	71	0.2 (0.2-0.3)	1.11 (0.74-1.61)
Ankle	37	0.2 (0.2-0.3)	74	0.2 (0.2-0.3)	0.97 (0.66-1.44)
Time loss					
1 to 7 days	127	0.8 (0.6-0.9)	259	0.8 (0.7-0.9)	0.95 (0.77-1.18)
8 to 21 days	71	0.4 (0.3-0.5)	105	0.3 (0.3-0.4)	1.32 (0.97-1.78)
>21 days	46	0.3 (0.2-0.4)	93	0.3 (0.2-0.3)	0.96 (0.68-1.37)

** Significant difference in injury incidence between the preseason and the competitive season*

Risk of injury on third generation artificial turf (Paper III)

From the 2004 season, the injury surveillance system included information on exposure to artificial turf and the playing surface on which injuries were sustained. We found no difference in the overall incidence of injury between grass and artificial turf (RR: 1.01, 95% CI 0.87 to 1.15). However, when comparing the injury incidence between the two surfaces, the difference in exposure on the two surfaces is confounded by the match to training factor. The proportion of match exposure is higher on natural grass compared to artificial turf; in addition, injuries are more common during matches. However, we found no difference between grass and artificial turf during matches (RR: 1.04, 95% CI 0.86 to 1.25), nor during training (RR: 1.07, 95% CI 0.87 to 1.32). This is in accordance with previous studies comparing the risk of injury on third generation artificial turf to natural grass (Ekstrand et al., 2006; Fuller et al., 2007b; Fuller et al., 2007a; Steffen et al., 2007; Soligard et al., 2012; Aoki et al., 2010; Ekstrand et al., 2011a). In contrast, a recent study from Swedish and Norwegian football found an increased risk of training and overuse injuries among clubs with artificial turf on their home venue (Kristenson et al., 2013a).

We could not observe any significant differences in injury incidence between grass and artificial turf for match or training injuries in any of the subcategories of injury location, severity or injury type (table 8). However, we did observe a trend towards an increased incidence of knee and ankle sprains on artificial turf, albeit only during matches. Ekstrand et al. (2006) found a significant difference and Steffen et al. (2007) a trend towards an increased incidence of ankle sprains on artificial turf. Ekstrand et al. (2006) also saw a trend towards a reduced incidence of muscle injuries on artificial turf; there was no indication of this in our study.

We found a tendency towards an increased incidence of severe injuries on artificial turf; however, we used different severity categories than the consensus statement (Fuller et al., 2006). Studies from professional and youth football found a tendency towards an increased incidence of severe injuries on artificial turf (Ekstrand et al., 2006; Steffen et al., 2007). In contrast, Fuller and co-workers (2007), found no significant difference in severity, nature or cause of injuries between natural grass and artificial turf.

Table 8. Characteristics of acute match and training injuries on grass and artificial turf. The incidences are reported per 1000 h of exposure (with 95% CI). Rate ratios between injuries on grass and artificial turf are shown with 95% CI, with grass as the reference group.

	Grass		Artificial turf		Artificial turf vs. grass
	Injuries	Incidence	Injuries	Incidence	Rate ratio
Acute match injuries (n=668)					
Injury type					
Fracture	34	1.1 (0.7-1.5)	7	0.9 (0.2-1.5)	0.79 (0.35-1.78)
Sprain	165	5.3 (4.5-6.1)	57	7.1 (5.2-8.9)	1.33 (0.98-1.79)
Strain	157	5.1 (4.3-5.9)	36	4.5 (3.0-5.9)	0.88 (0.61-1.27)
Contusion	119	3.8 (3.2-4.5)	32	4.0 (2.6-5.4)	1.03 (0.70-1.53)
Cut	12	0.4 (0.2-0.6)	6	0.7 (0.1-1.3)	1.92 (0.72-5.12)
Nervous system	26	0.8 (0.5-1.2)	3	0.4 (0.0-0.8)	0.44 (0.13-1.47)
Other	13	0.4 (0.2-0.6)	1	0.1 (-0.1-0.4)	0.30 (0.04-2.26)
Body location					
Head/neck	61	2.0 (1.5-2.5)	9	1.1 (0.4-1.8)	0.57 (0.28-1.14)
Concussion	42	1.4 (0.9-1.8)	5	0.6 (0.1-1.2)	0.46 (0.18-1.16)
Upper extremity	18	0.6 (0.3-0.9)	3	0.4 (0.0-0.8)	0.64 (0.19-2.17)
Trunk	34	1.1 (0.7-1.5)	12	1.5 (0.6-2.3)	1.36 (0.70-2.62)
Lower extremity					
Groin	48	1.6 (1.1-2.0)	11	1.4 (0.6-2.2)	0.88 (0.46-1.70)
Thigh	107	3.5 (2.8-4.1)	31	3.9 (2.5-5.2)	1.11 (0.75-1.66)
Knee	83	2.7 (2.1-3.3)	26	3.2 (2.0-4.5)	1.20 (0.78-1.87)
Calf	64	2.1 (1.6-2.6)	10	1.2 (0.5-2.0)	0.60 (0.31-1.17)
Ankle	86	2.8 (2.2-3.4)	30	3.7 (2.4-5.1)	1.34 (0.89-2.03)
Foot	25	0.8 (0.5-1.1)	10	1.2 (0.5-2.0)	1.54 (0.74-3.20)
Time loss					
1 to 7 days	263	8.5 (7.5-9.5)	64	8.0 (6.0-9.9)	0.94 (0.71-1.23)
8 to 21 days	151	4.9 (4.1-5.7)	39	4.8 (3.3-6.4)	0.99 (0.70-1.41)
>21 days	112	3.6 (3.0-4.3)	39	4.8 (3.3-6.4)	1.34 (0.93-1.93)
Acute training injuries (n=399)					
Injury type					
Fracture	13	0.1 (0.0-0.1)	5	0.1 (0.0-0.1)	0.90 (0.32-2.53)
Sprain	114	0.7 (0.6-0.9)	43	0.6 (0.5-0.8)	0.88 (0.62-1.26)
Strain	101	0.6 (0.5-0.8)	52	0.8 (0.6-1.0)	1.21 (0.86-1.69)
Contusion	34	0.2 (0.1-0.3)	21	0.3 (0.2-0.5)	1.45 (0.84-2.49)
Cut	1		0		
Nervous system	4		2		
Other	7		2		
Body location					
Head/neck	8		1		
Concussion	6		1		
Upper extremity	16	0.1 (0.1-0.2)	5	0.1 (0.0-0.1)	0.73 (0.27-2.00)
Trunk	19	0.1 (0.1-0.2)	10	0.2 (0.1-0.2)	1.23 (0.57-2.65)
Lower extremity					
Groin	21	0.1 (0.1-0.2)	10	0.2 (0.1-0.2)	1.12 (0.53-2.37)
Thigh	74	0.5 (0.4-0.6)	35	0.6 (0.4-0.7)	1.11 (0.74-1.66)
Knee	52	0.3 (0.2-0.4)	27	0.4 (0.3-0.6)	1.22 (0.76-1.94)
Calf	22	0.1 (0.1-0.2)	10	0.2 (0.1-0.2)	1.07 (0.50-2.25)
Ankle	52	0.3 (0.2-0.4)	21	0.3 (0.2-0.5)	0.95 (0.57-1.57)
Foot	10	0.1 (0.0-0.1)	6	0.1 (0.0-0.2)	1.41 (0.51-3.87)
Time loss					
1 to 7 days	152	1.0 (0.8-1.1)	50	0.8 (0.5-1.0)	0.77 (0.56-1.06)
8 to 21 days	74	0.5 (0.4-0.6)	45	0.7 (0.5-0,9)	1.43 (0.98-2.06)
>21 days	48	0.3 (0.2-0.4)	30	0.5 (0.3-0.6)	1.47 (0.93-2.31)

Video analysis of situations with a high propensity for injury in Norwegian male professional football; a comparison between 2000 and 2010 (Paper IV)

The aim of this study was to compare the rate of high-risk injury incidents between the 2000 and 2010 seasons in Norwegian male professional football, and to compare duel characteristics between the two seasons. We observed a higher rate of both opponent-to-player contact incidents and non-contact incidents in the 2010 season. No difference was observed in the rate of incidents caused by teammate-to-player contact or ball-to-player contact (Table 9).

Table 9. Characteristics of incidents (n=1 287) from video analysis of all games (n=414). Rate is reported as the number of incidents per 1000 player-match hours with 95% confidence intervals (CI). Rate ratios between the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

	2000		2010		2000 vs. 2010
	Incidents	Rate	Incidents	Rate	Rate ratio
Contact opponent	353	62.7 (56.1-69.2)	734	92.7 (86.0-99.4)	1.48 (1.30-1.68)
Contact teammate	18	3.2 (1.7-4.7)	28	3.5 (2.2-4.8)	1.11 (0.61-2.00)
Non-contact	29	5.1 (3.3-7.0)	68	8.6 (6.5-10.6)	1.67 (1.08-2.58)
Contact ball	17	3.0 (1.6-4.5)	32	4.0 (2.6-5.4)	1.34 (0.74-2.41)
Other	2	0.4 (-0.1-0-8)	6	0.8 (0.2-1.4)	2.13 (0.43-10)

Tackling and heading characteristics

Table 10. Characteristics of head incidents due to opponent-to-player contact from video analysis of all games (n=414). Rate is reported as the number of incidents per 1000 player-match hours with 95% CI. Rate ratios between incidents in the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

	2000		2010		2000 vs. 2010
	Incidents	Rate	Incidents	Rate	Rate ratio
Duel type					
Heading duel	87	15.4 (12.2-18.7)	215	27.1 (23.5-30.8)	1.76 (1.37-2.26)
Tackling duel	202	35.9 (30.9-40.8)	437	55.2 (50.0-60.4)	1.54 (1.30-1.82)
Other duel	64	11.4 (8.6-14.1)	82	10.4 (8.1-12.6)	0.91 (0.66-1.26)
Body location					
Head/neck	100	17.8 (14.3-21.2)	226	28.5 (24.8-32.3)	1.61 (1.27-2.03)
Upper extremity	8	1.4 (0.4-2.4)	16	2.0 (1.0-3.0)	1.42 (0.61-3.32)
Trunk	41	7.3 (5.1-9.5)	91	11.5 (9.1-13.9)	1.58 (1.09-2.28)
Lower extremity					
Thigh	12	2.1 (0.9-3.3)	39	4.9 (3.4-6.5)	2.31 (1.21-4.42)
Knee	26	4.6 (2.8-6.4)	49	6.2 (4.5-7.9)	1.34 (0.83-2.16)
Lower leg/ankle	166	29.5 (25.0-34.0)	313	39.5 (35.1-43.9)	1.34 (1.11-1.62)
All head situations (n=326)					
Head-to-head	46	8.2 (5.8-10.5)	74	9.3 (7.2-11.5)	1.14 (0.79-1.65)
Arm-to-head	35	6.2 (4.2-8.3)	109	13.8 (11.2-16.3)	2.22 (1.51-3.24)
Shoulder-to-head	2	0.4 (-0.1-0.8)	10	1.3 (0.5-2.0)	3.56 (0.78-16)
Trunk-to-head	1	0.2 (-0.2-0.5)	10	1.3 (0.5-2.0)	7.11 (1 (0.91-55)
Leg-to-head	15	2.7 (1.3-4.0)	21	2.7 (1.5-3.8)	1.00 (0.51-1.93)

We found a higher rate of incidents caused by opponent-to-player contact, both for heading and tackling duels in the 2010 season. We also found a higher rate of head, trunk, thigh and lower leg/ankle contact incidents in the 2010 season (Table 10), as well as an increased incidence of arm-to-head incidents in the 2010 season. No differences were found in the incidence of head incidents caused by other mechanisms.

We found an increased incidence of tackles from all directions, all tackling modes, and one-footed tackles. There was an increase in tackles having contact with the ball prior to player impact and tackles with no ball contact prior to player impact. However, we found no difference in the incidence of two-footed tackles.

Referee decision

We found no differences in the referee decision or sanctions of foul play between the two seasons. We had no referee panel for the referees' decisions during matches; thus, we were not able to assess whether the decision called by the referee was correct according to expert opinion. After the 2000 season, the referees' decisions were reviewed retrospectively by a Norwegian FIFA referee panel, concluding that the judgments of the match referee were according to the existing interpretation of the Laws of the Game. It was noted, however, that there might be a need for an improvement of the laws in order to protect the players from dangerous play (Andersen et al., 2004b).

Player-to-player contact situations

The observed increase in incidents from the 2000 season to the 2010 season could have been due to an increased incidence of player-to-player contacts during each match in the 2010 season. Therefore, we analyzed one home match and one away match for each team participating in the two seasons, 14 games from the 2000 season and 16 games from the 2010 season (Table 11).

Table 11. Characteristics of player-to-player contact situations (n=3 526) from video analysis of 30 randomly picked matches. Situations rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

	2000		2010		2000 vs. 2010
	Situations	Rate	Situations	Rate	Rate ratio
Duel type (n=3 526)					
Heading duel	879	1903 (1777-2028)	816	1545 (1439-1652)	0.81 (0.74-0.89)
Tackling duel	637	1379 (1272-1486)	462	1233 (1138-1328)	0.89 (0.80-1.00)
Other duel	271	587 (517-656)	272	515 (454-576)	0.87 (0.74-1.04)

We found that the overall incidence of player-to-player contact was lower in the 2010 season compared to the 2000 season, including the incidences of tackling and heading duels. Thus, the increase in the rate of incidents was not due to a general increase in number of situations with player to opponent contact, but must result from a difference in dueling behavior, i.e. a rougher style of play with more aggressive dueling technique.

Previous studies on injury mechanisms in football have found that most ankle and head injuries are caused by player-to-player contact (Giza et al., 2003; Andersen et al., 2004c; Andersen et al., 2004a). For ankle injuries, the most common cause of contact injury is being tackled to the weight-bearing limb, involving lateral and medial forces and the tackler staying on his feet (Giza et al., 2003; Fuller et al., 2004c; Andersen et al., 2004c). The most common causes of head injuries and incidents are typically heading duels, arm-to-head contact, followed by head-to-head contact (Andersen et al., 2004a). It is therefore a concern that we found an increased rate of duel incidents, and that the increased frequency of head incidents was a result of increased arm-to-head contact.

Stricter rule enforcement – lower incidence of arm-to-head contact incidents (Paper V)

This is the first study to evaluate the effect of changes in the interpretation of the Laws of the game on the risk of injury in male professional football. We were not able to detect any difference in the overall incident rate between the two seasons (Table 12).

Table 12. Characteristics of incidents (n=1721) from video analysis of all games (n=240 each season). Rate is reported as the number of incidents per 1000 player-match hours with 95% confidence intervals (CI). Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

	2010		2011		2010 vs. 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
Contact opponent	734	92.7 (86.0-99.4)	687	86.7 (80.3-93.2)	0.94 (0.84-1.04)
Contact teammate	28	3.5 (2.2-4.8)	28	3.5 (2.2-4.8)	1.00 (0.59-1.69)
Non-contact	68	8.6 (6.5-10.6)	91	11.5 (9.1-13.9)	1.34 (0.98-1.83)
Contact ball	32	4.0 (2.6-5.4)	45	5.7 (4.0-7.3)	1.41 (0.89-2.21)
Other	6	0.8 (0.2-1.4)	2	0.3 (-0.1-0.6)	0.33 (0.07-1.65)

Heading and tackling characteristics

We found a reduced frequency of contact head incidents (Table 13); subsequently we found a lower incidence of arm-to-head contact incidents after the implementation of stricter rule enforcement (Table 14). No differences were found in the incidence of other mechanisms for all head incidents or during heading duels.

Table 13. Characteristics of incidents due to opponent-to-player contact (n=1421) from video analysis of all games (n=240 each season). Incident rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

	2010		2011		2010 vs. 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
Duel type					
Heading duel	215	27.1 (23.5-30.8)	177	22.3 (19.1-25.6)	0.82 (0.68-1.00)
Tackling duel	437	55.2 (50.0-60.4)	424	53.5 (48.4-58.6)	0.97 (0.85-1.11)
Other duel	82	10.4 (8.1-12.6)	86	10.9 (8.6-13.2)	1.05 (0.78-1.42)
Body location					
Head/neck	226	28.5 (24.8-32.3)	184	23.2 (19.9-26.6)	0.81 (0.67-0.99)
Upper extremity	16	2.0 (1.0-3.0)	16	2.0 (1.0-3.0)	1.00 (0.50-2.00)
Trunk	91	11.5 (9.1-13.9)	108	13.6 (11.1-16.2)	1.18 (0.90-1.57)
Lower extremity					
Thigh	39	4.9 (3.4-6.5)	56	7.1 (5.2-8.9)	1.44 (0.95-2.16)
Knee	49	6.2 (4.5-7.9)	39	4.9 (3.4-6.5)	0.80 (0.52-1.21)
Lower leg/ankle	313	39.5 (35.1-43.9)	284	35.9 (31.7-40.0)	0.91 (0.77-1.07)

Previous studies on injury mechanisms in football have showed that most head injuries occurs in heading duels, with subsequent arm-to-head contact or head-to-head contact (Andersen et al., 2004a; Fuller et al., 2004c). Incidents and injuries caused by head-to-head contact are normally not deliberate, while arm-to-head incidents sometimes are. Thus, it is encouraging that we were able to detect a reduced rate of arm-to-head contact incidents after the introduction of stricter rule enforcement, explicitly sanctioning intentional high elbows with an automatic red card.

Table 14. Characteristics of head incidents due to opponent-to-player contact (n=410) from video analysis of all games (n=240 each season). Rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

	2010		2011		2010 vs. 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
All head incidents (n=410)					
Head-to-head	74	9.3 (7.2-11.5)	70	8.8 (6.8-10.9)	0.95 (0.68-1.31)
Arm-to-head	109	13.8 (11.2-16.3)	79	10.0 (7.8-12.2)	0.72 (0.54-0.97)
Shoulder-to-head	10	1.3 (0.5-2.0)	11	1.43 (0.65-2.2)	1.10 (0.47-2.59)
Trunk-to-head	10	1.3 (0.5-2.0)	7	0.9 (0.2-1.5)	0.70 (0.27-1.84)
Leg-to-head	21	2.7 (1.5-3.8)	16	2.0 (1.0-3.0)	0.76 (0.40-1.46)
Other-head	2	-	1	-	-
Heading duel (n=286)					
Head-to-head	68	8.6 (6.5-10.6)	66	8.3 (6.5-10.3)	0.97 (0.69-1.36)
Arm-to-head	84	10.6 (8.3-12.9)	47	5.9 (4.2-7.6)	0.56 (0.39-0.80)
Shoulder-to-head	6	0.8 (0.2-1.4)	3	0.4 (0.0-0.8)	0.50 (0.13-2.00)
Trunk-to-head	2	0.3 (-0.1-0.6)	4	0.5 (0.0-1.0)	2.00 (0.37-10)
Leg-to-head	3	0.4 (0.0-0.8)	2	0.3 (-0.1-0.6)	0.67 (0.11-4.00)
Other head	0	-	1	-	-

We found a reduced incident rate of passive tackles from the front (RR 0.76, 95% CI 0.59 to 0.98). There were no differences for passive tackle actions, tackling mode, tackling timing or tackles with ball contact. Thus, the stricter rule enforcement did not alter player behavior substantially. Correspondingly, we were not able to reduce the rate of lower leg/ankle incidents.

For ankle injuries, the most common cause of contact injury is being tackled to the weight bearing limb, involving lateral and medial forces and the tackler staying on his feet (Giza et al., 2003; Fuller et al., 2004c; Andersen et al., 2004c). Therefore, we focused on the sanctioning of two-foot tackles as well as tackles with excessive force with an automatic red card. Still, we found no difference in characteristics for passive tackles between the two seasons, indicating that the intervention did not change player behavior in these incidents. Correspondingly, we were not able to reduce the rate of lower leg/ankle incidents.

Decision of the referee

An important part of this study was the decision of the referees. Did they award free kicks and sanctions as intended, with a straight red card for two-foot tackles, tackles with excessive force and intentional high elbows? The referee decisions are characterized in table 15.

Table 15.Referee decision for different incident types caused by opponent-to-player contact from video analysis of all games (n=240 each season). Proportions were compared using a χ2 test.

	2010		2011		2010 vs. 2011
	Incidents	Percentage	Incidents	Percentage	p-value
Opponent-to-player contact (n=1421)					
Free kick	379	52%	367	53%	0.50
Sanctioned	128	34%	114	31%	0.38
Passive tackling incidents (n=724)					
Free kick	253	67%	262	76%	0.01
Sanctioned	108	43%	103	39%	0.44
Arm-to-head contact (n=188)					
Free kick	38	35%	30	38%	0.66
Sanctioned	6	16%	4	13%	0.89
Arm-to-head contact in heading duels (n=131)					
Free kick	34	41%	17	36%	0.63
Sanctioned	5	15%	1	6%	0.36

Despite a lower incidence of head incidents and no change in the incidence of ankle incidents, we found that a free-kick was awarded in a higher proportion of the passive tackling incidents in the 2011 season. However, no difference was found in the sanctioning of the incidents. We also found that all straight red cards (4) awarded in the 2010 and 2011 season were given for tackling incidents and no straight red cards were given for arm-to-head contact. This might indicate that it is more difficult for the referees to recognize arm-to-head incidents and that the reduction in head incidents and arm-to-head incidents was due to changes in player behavior. Since the 2006 season, the fourth official has become an integral part of the officiating team and the role is to advise the match referee. In recent tournaments, UEFA has introduced two goal-line officials to ensure that the Laws of the Game are upheld, especially within the penalty box. This expansion of the refereeing team may help to ensure stricter rule enforcement.

In an assessment of player error as an injury causation factor in international football it was found that human error during tackling, inadequacies in the Laws of the Game and/or their application by match referees were equally responsible for the high levels of injury observed (Fuller et al., 2004b). In a study of psychological characteristics of football players Junge et al. (2000) found that players have insufficient respect for the Laws of the Game and its regulation. In addition, nearly all players were ready to commit a “professional foul” if necessary and a majority stated that concealed fouls were a part of the game. However, we have not evaluated player attitudes to stricter rule enforcement, but it is possible that the increased focus on the potential of injury through arm-to-head contact and the stricter rule enforcement have changed their attitude towards safer behavior in heading duels.

Player-to-player contact situations

We conducted a separate video analysis where 32 games were analyzed for all situations involving opponent contact. In this analysis we found no difference in the overall incidence of player-to-player contact between the two seasons. We could not detect any difference in the incidence of heading or tackling duels, nor the incidence of arm-to-head contact in heading duels. Thus, there is no reason to assume that the reduced incidence of head incidents and head incidents caused by arm-to-head contact was due to an overall change in the style of play or intensity of matches from the 2010 to the 2011 season.

Injury registration

We found no difference in the overall match injury incidence, contact injury incidence or non-contact injury incidence between the 2010 season and the 2011 season. We found a reduced rate of acute contact injuries of minimal severity. No difference was detected between the two seasons for injury type and injury location.

General methodological considerations

A strength of Paper I is the participation rate, 13 of 14 clubs participated and 296 of 310 (96%) of the players were interviewed, leading to a high validity of the study. Paper II and III include a high number of time-loss injuries, thus reducing the risk of type II errors. Nevertheless, there still is a possibility of a type II error resulting from limited data, especially when comparing the incidences in subcategories of injuries and incidents (e.g. for a specific injury location, type or severity). Another strength of Paper II and III is the validation of the injury registration method. The medical staff of Norwegian professional clubs fails to report about 20% of all time-loss injuries. However, no difference related to surface when the injury was sustained, injury type, severity, nor body part was detected. Thus, although the overall injury incidence in Paper II and Paper III is probably underestimated, but is unlikely to have interfered with our comparison of subcategories.

A weakness of our injury surveillance system is the limited information about injury risk factors and injury mechanisms. This combined with the lack of individual exposure data limits our ability to assess whether there have been any changes in the causes of injuries over the study period. We are therefore not able to adjust for the two main factors contributing to surface-related injuries; the hardness of the playing ground and the shoe-surface traction (Nigg and Yeadon, 1987).

As mentioned above, the current set-up of the injury surveillance system, using a "time-loss"-definition, leads to an underestimation of the prevalence and incidence of overuse injuries (Bahr, 2009). Therefore, we cannot exclude that the incidence of overuse or acute injuries not leading to time loss from matches or training has increased (Paper II). Secondly, overuse injuries are defined as being the result of repeated micro-trauma without a single, identifiable event responsible for the injury (Fuller et al., 2006). Therefore, even if a "physical complaint"-definition were used, an overuse injury cannot be attributed to one specific training session or match and, hence, to one of the two turf types in question in Paper III.

A possible limitation of Paper IV and Paper V is the video quality. However, during the recent decade the image quality, the number of camera views and the resolution has improved. In the 2000 season 11% of the matches were broadcast using more than three cameras, whereas in the 2010 and 2011 season all games were broadcasted with at least three cameras, making it easier to capture incidents. Thus, the incident rate might have been underestimated in the 2000 season, leading to an overestimation of the difference between the 2000 season and the 2010 season. The 15 s parameter was chosen because that was thought to be long enough to avoid incidents where players intentionally stayed down either to rest, simulate or to delay playing time. Paper IV and V did not include a referee panel to evaluate the decisions of the referees; thus, we are not able to assess whether the decisions were correct according to expert opinion.

Substantial changes in the injury recording methodology were made prior to the 2010 season, as the UEFA Injury Study Protocol was implemented in Norwegian professional football. Thus, a major limitation of Paper IV is that we cannot compare the actual injury rate between the 2000 and 2010 seasons; we therefore do not know if the increase observed in the rate of incidents also can be extrapolated to an increase in injury rate.

A strength of Paper V is the wide support of the study within Norwegian football. All stakeholders in Norwegian football were informed of the stricter interpretation of the rules and all participating parties were thoroughly informed prior to the league start in March 2011.

In Paper V a reduction of contact injuries would ideally serve as end-point. However, with an expected total of 50 contact injuries, the effect of the stricter rule enforcement would have required a 70% decrease in injury incidence in order to detect it. However, only 47 of the 1421 (3%) incidents resulted in an injury recorded by the medical staff. In addition, video analysis did not capture 35 of the injuries recorded by the medical staff. Despite this, we do believe incidents serve as a valid surrogate measure of injury risk, as the incidents represents events with a propensity for injury (Andersen et al., 2004d; Arnason et al., 2004b; Fuller et al., 2004c).

With an RCT not being possible, a pre-/post-intervention design was employed, where data from the 2011 season was compared to 2010 season data. There have been no other changes in the Norwegian male professional league system or style of play that we can think of which could explain the observed reduction in head incidents, or head incidents caused by arm-to-head contact.

Conclusions

I. Prospective injury surveillance by team medical staff in Norwegian male professional football underestimates the incidence of time-loss injuries by at least one-fifth (Paper I).

II. The six-season injury registration documented that the overall incidence of acute match injuries in Norwegian male professional football increased by 6% per year during the study period, although this increase was not fully consistent across teams (Paper II)

III. No significant difference in training or match injury incidence was detected between the preseason and competitive season (Paper II).

IV. No significant differences were detected in injury rate or pattern between third-generation artificial turf and natural grass in Norwegian male professional football (Paper III).

V. We found an increased rate of non-contact and opponent-to-player contact incidents in both heading and tackling duels in the 2010 season compared to ten years earlier, even if there was no increase in the overall frequency of player-to-player contact situations (Paper IV).

VI. We found no significant differences in the overall rate of incidents after the introduction of stricter rule enforcement. However, the rate of head and arm-to-head incidents was lower (Paper V).

References

Alonso, J. M., Junge, A., Renstrom, P., Engebretsen, L., Mountjoy, M., Dvorak, J., (2009). Sports injuries surveillance during the 2007 IAAF World Athletics Championships. Clin.J.Sport Med. 19**,** 26-32.

Altman, D. G., (1991). Some common problems in medical research. In: Altman, D. G. (Ed.), Practical statistics for medical research. London: Chapman & Hall, pp. 403-409.

Andersen, T. E., Arnason, A., Engebretsen, L., Bahr, R., (2004a). Mechanisms of head injuries in elite football. Br.J.Sports Med. 38**,** 690-696.

Andersen, T. E., Engebretsen, L., Bahr, R., (2004b). Rule violations as a cause of injuries in male norwegian professional football: are the referees doing their job? Am.J.Sports Med. 32**,** 62S-68S.

Andersen, T. E., Flørenes, T. W., Arnason, A., Bahr, R., (2004c). Video analysis of the mechanisms for ankle injuries in football. Am.J.Sports Med. 32**,** 69S-79S.

Andersen, T. E., Tenga, A., Engebretsen, L., Bahr, R., (2004d). Video analysis of injuries and incidents in Norwegian professional football. Br.J.Sports Med. 38**,** 626-631.

Andersson, H., Ekblom, B., Krustrup, P., (2008). Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. J.Sports Sci. 26**,** 113-122.

Aoki, H., Kohno, T., Fujiya, H., Kato, H., Yatabe, K., Morikawa, T., Seki, J., (2010). Incidence of injury among adolescent soccer players: a comparative study of artificial and natural grass turfs. Clin.J.Sport Med. 20**,** 1-7.

Arnason, A., Andersen, T. E., Holme, I., Engebretsen, L., Bahr, R., (2008). Prevention of hamstring strains in elite soccer: an intervention study. Scand.J.Med.Sci.Sports 18**,** 40-48.

Arnason, A., Engebretsen, L., Bahr, R., (2005). No effect of a video-based awareness program on the rate of soccer injuries. Am.J.Sports Med. 33**,** 77-84.

Arnason, A., Gudmundsson, A., Dahl, H. A., Johannsson, E., (1996). Soccer injuries in Iceland. Scand.J.Med.Sci.Sports 6**,** 40-45.

Arnason, A., Sigurdsson, S. B., Gudmundsson, A., Holme, I., Engebretsen, L., Bahr, R., (2004a). Risk factors for injuries in football. Am.J.Sports Med. 32**,** 5S-16S.

Arnason, A., Tenga, A., Engebretsen, L., Bahr, R., (2004b). A prospective video-based analysis of injury situations in elite male football: football incident analysis. Am.J.Sports Med. 32**,** 1459-1465.

Askling, C., Karlsson, J., Thorstensson, A., (2003). Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. Scand.J.Med.Sci.Sports 13**,** 244-250.

Bahr, R., (2009). No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. Br.J.Sports Med. 43**,** 966-972.

Bahr, R., Holme, I., (2003). Risk factors for sports injuries--a methodological approach. Br.J.Sports Med. 37, 384-392.

Bahr, R., Kannus P, van Mechelen W., (2003). Epidemiology and Prevention of Sports Injuries. Textbook of Sports Medicine. Munksgaard, Copenhagen.

Bahr, R., Krosshaug, T., (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. Br.J.Sports Med. 39, 324-329.

Bahr, R., Reeser, J. C., (2003). Injuries among world-class professional beach volleyball players. The Federation Internationale de Volleyball beach volleyball injury study. Am.J.Sports Med. 31, 119-125.

Bathgate, A., Best, J. P., Craig, G., Jamieson, M., (2002). A prospective study of injuries to elite Australian rugby union players. Br.J.Sports Med. 36, 265-269.

Belanger, H. G., Vanderploeg, R. D., (2005). The neuropsychological impact of sports-related concussion: a meta-analysis. J.Int.Neuropsychol.Soc. 11, 345-357.

Best, J. P., McIntosh, A. S., Savage, T. N., (2005). Rugby World Cup 2003 injury surveillance project. Br.J.Sports Med. 39, 812-817.

Caraffa, A., Cerulli, G., Projetti, M., Aisa, G., Rizzo, A., (1996). Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. Knee.Surg.Sports Traumatol.Arthrosc. 4, 19-21.

Carling, C., Le, G. F., Dupont, G., (2012). Are physical performance and injury risk in a professional soccer team in match-play affected over a prolonged period of fixture congestion? Int.J.Sports Med. 33, 36-42.

Chomiak, J., Junge, A., Peterson, L., Dvorak, J., (2000). Severe injuries in football players. Influencing factors. Am.J.Sports Med. 28, S58-S68.

Clarsen, B., Krosshaug, T., Bahr, R., (2010). Overuse injuries in professional road cyclists. Am.J.Sports Med. 38, 2494-2501.

Clarsen, B., Myklebust, G., Bahr, R., (2012). Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology. Br.J.Sports Med.

Croisier, J. L., Ganteaume, S., Binet, J., Genty, M., Ferret, J. M., (2008). Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. Am.J.Sports Med. 36, 1469-1475.

Dick, R., Agel, J., Marshall, S. W., (2009). National Collegiate Athletic Association Injury Surveillance System commentaries: introduction and methods. J.Athl.Train. 44, 173-182.

Drawer, S., Fuller, C. W., (2001). Propensity for osteoarthritis and lower limb joint pain in retired professional soccer players. Br.J.Sports Med. 35, 402-408.

Drawer, S., Fuller, C. W., (2002). Evaluating the level of injury in English professional football using a risk based assessment process. Br.J.Sports Med. 36, 446-451.

Dupont, G., Nedelec, M., McCall, A., McCormack, D., Berthoin, S., Wisloff, U., (2010). Effect of 2 soccer matches in a week on physical performance and injury rate. Am.J.Sports Med. 38, 1752-1758.

Dvorak, J., Junge, A., (2000). Football injuries and physical symptoms. A review of the literature. Am.J.Sports Med. 28, S3-S9.

Dvorak, J., Junge, A., Chomiak, J., Graf-Baumann, T., Peterson, L., Rosch, D., Hodgson, R., (2000). Risk factor analysis for injuries in football players. Possibilities for a prevention program. Am.J.Sports Med. 28, S69-S74.

Dvorak, J., Junge, A., Derman, W., Schwellnus, M., (2011). Injuries and illnesses of football players during the 2010 FIFA World Cup. Br.J.Sports Med. 45, 626-630.

Dvorak, J., Junge, A., Grimm, K., Kirkendall, D., (2007). Medical report from the 2006 FIFA World Cup Germany. Br.J.Sports Med. 41, 578-581.

Eirale, C., Farooq, A., Smiley, F. A., Tol, J. L., Chalabi, H., (2013a). Epidemiology of football injuries in Asia: a prospective study in Qatar. J.Sci.Med.Sport 16, 113-117.

Eirale, C., Tol, J. L., Farooq, A., Smiley, F., Chalabi, H., (2013b). Low injury rate strongly correlates with team success in Qatari professional football. Br.J.Sports Med. 47, 807-808.

Ekstrand, J., Gillquist, J., (1983). Soccer injuries and their mechanisms: a prospective study. Med.Sci.Sports Exerc. 15, 267-270.

Ekstrand, J., Gillquist, J., Liljedahl, S. O., (1983). Prevention of soccer injuries. Supervision by doctor and physiotherapist. Am.J.Sports Med. 11, 116-120.

Ekstrand, J., Hägglund, M., Fuller, C. W., (2011a). Comparison of injuries sustained on artificial turf and grass by male and female elite football players. Scand.J.Med.Sci.Sports 21, 824-832.

Ekstrand, J., Hägglund, M., Wálden, M., (2011b). Epidemiology of muscle injuries in professional football (soccer). Am.J.Sports Med. 39, 1226-1232.

Ekstrand, J., Hägglund, M., Wálden, M., (2011c). Injury incidence and injury patterns in professional football - the UEFA injury study. Br.J.Sports Med. 45, 553-558.

Ekstrand, J., Roos, H., Tropp, H., (1990). Normal course of events amongst Swedish soccer players: an 8-year follow-up study. Br.J.Sports Med. 24, 117-119.

Ekstrand, J., Timpka, T., Hägglund, M., (2006). The risk for injury when playing elite football on artificial turf versus natural grass - a prospective two-cohort study. Br.J.Sports Med.

Emery, C. A., (2005). Injury prevention and future research. Med.Sport Sci. 48, 179-200.

Engebretsen, A. H., Myklebust, G., Holme, I., Engebretsen, L., Bahr, R., (2008). Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. Am.J.Sports Med. 36, 1052-1060.

Engebretsen, A. H., Myklebust, G., Holme, I., Engebretsen, L., Bahr, R., (2010a). Intrinsic risk factors for acute ankle injuries among male soccer players: a prospective cohort study. Scand.J.Med.Sci.Sports 20, 403-410.

Engebretsen, A. H., Myklebust, G., Holme, I., Engebretsen, L., Bahr, R., (2010b). Intrinsic risk factors for acute knee injuries among male football players: a prospective cohort study. Scand.J.Med.Sci.Sports.

Engebretsen, A. H., Myklebust, G., Holme, I., Engebretsen, L., Bahr, R., (2010c). Intrinsic risk factors for groin injuries among male soccer players: a prospective cohort study. Am.J.Sports Med. 38, 2051-2057.

Engebretsen, A. H., Myklebust, G., Holme, I., Engebretsen, L., Bahr, R., (2010d). Intrinsic risk factors for hamstring injuries among male soccer players: a prospective cohort study. Am.J.Sports Med. 38, 1147-1153.

Engebretsen, L., Kase, T., (1987). [Soccer injuries and artificial turf]. Tidsskr.Nor Laegeforen. 107, 2215-2217.

Engström, B., Forssblad, M., Johansson, C., Tornkvist, H., (1990). Does a major knee injury definitely sideline an elite soccer player? Am.J.Sports Med. 18, 101-105.

Faude, O., Junge, A., Kindermann, W., Dvorak, J., (2006). Risk factors for injuries in elite female soccer players. Br.J.Sports Med. 40, 785-790.

FIFA, (2009). Football turf booklet.

FIFA, (2011). Laws of the Game.

Flørenes, T. W., Nordsletten, L., Heir, S., Bahr, R., (2011). Recording injuries among elite skiers and snowboarders - a methodological study. Scand.J.Med.Sci.Sports 21, 196-205.

Fonseca, S. S., Victora, C. G., Halpern, R., Lima, R., Barros, F. C., (2002). Comparison of two methods for assessing injuries among preschool children. Inj.Prev. 8, 79-82.

Foss, I. S., Holme, I., Bahr, R., (2012). The prevalence of low back pain among former elite cross-country skiers, rowers, orienteerers, and nonathletes: a 10-year cohort study. Am.J.Sports Med. 40, 2610-2616.

Fredberg, U., Bolvig, L., (2002). Significance of ultrasonographically detected asymptomatic tendinosis in the patellar and achilles tendons of elite soccer players: a longitudinal study. Am.J.Sports Med. 30, 488-491.

Froholdt, A., Olsen, O. E., Bahr, R., (2009). Low risk of injuries among children playing organized soccer: a prospective cohort study. Am.J.Sports Med. 37, 1155-1160.

Fuller, C. W., (1995). Implications of health and safety legislation for the professional sportsperson. Br.J.Sports Med. 29, 5-9.

Fuller, C. W., Dick, R. W., Corlette, J., Schmalz, R., (2007a). Comparison of the incidence, nature and cause of injuries sustained on grass and new generation artificial turf by male and female football players. Part 1: match injuries. Br.J.Sports Med. 41 Suppl 1, i20-i26.

Fuller, C. W., Dick, R. W., Corlette, J., Schmalz, R., (2007b). Comparison of the incidence, nature and cause of injuries sustained on grass and new generation artificial turf by male and female football players. Part 2: training injuries. Br.J.Sports Med. 41 Suppl 1, i27-i32.

Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., Hägglund, M., McCrory, P., Meeuwisse, W. H., (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. Clin.J.Sport Med. 16**,** 97-106.

Fuller, C. W., Junge, A., Dvorak, J., (2004a). An assessment of football referees' decisions in incidents leading to player injuries. Am.J.Sports Med. 32**,** 17S-22S.

Fuller, C. W., Smith, G. L., Junge, A., Dvorak, J., (2004b). An assessment of player error as an injury causation factor in international football. Am.J.Sports Med. 32**,** 28S-35S.

Fuller, C. W., Smith, G. L., Junge, A., Dvorak, J., (2004c). The influence of tackle parameters on the propensity for injury in international football. Am.J.Sports Med. 32**,** 43S-53S.

Gail, M., Benichou, J., (2000). Sample Size for Epidemiologic Studies. Encyclopedia of epidemiologi methods. pp. 784-786.

Gammelsæter, H., Jacobsen, S., (2007). Et tiår etter Bosman: Konsekvenser for utviklingen av norsk toppfotball.

Giza, E., Fuller, C., Junge, A., Dvorak, J., (2003). Mechanisms of foot and ankle injuries in soccer. Am.J.Sports Med. 31**,** 550-554.

Guskiewicz, K. M., Marshall, S. W., Bailes, J., McCrea, M., Harding, H. P., Jr., Matthews, A., Mihalik, J. R., Cantu, R. C., (2007). Recurrent concussion and risk of depression in retired professional football players. Med.Sci.Sports Exerc. 39**,** 903-909.

Haavik, Y., (2013). NFF i tall.

Hägglund, M., Wálden, M., Bahr, R., Ekstrand, J., (2005a). Methods for epidemiological study of injuries to professional football players: developing the UEFA model. Br.J.Sports Med. 39**,** 340-346.

Hägglund, M., Wálden, M., Ekstrand, J., (2005b). Injury incidence and distribution in elite football--a prospective study of the Danish and the Swedish top divisions. Scand.J.Med.Sci.Sports 15**,** 21-28.

Hägglund, M., Wálden, M., Ekstrand, J., (2006). Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. Br.J.Sports Med. 40**,** 767-772.

Hägglund, M., Wálden, M., Ekstrand, J., (2007). Lower reinjury rate with a coach-controlled rehabilitation program in amateur male soccer: a randomized controlled trial. Am.J.Sports Med. 35**,** 1433-1442.

Hägglund, M., Wálden, M., Ekstrand, J., (2009). Injuries among male and female elite football players. Scand.J.Med.Sci.Sports 19**,** 819-827.

Hägglund, M., Walden, M., Magnusson, H., Kristenson, K., Bengtsson, H., Ekstrand, J., (2013). Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. Br.J.Sports Med.

Harmon, K. G., Drezner, J. A., Gammons, M., Guskiewicz, K. M., Halstead, M., Herring, S. A., Kutcher, J. S., Pana, A., Putukian, M., Roberts, W. O., (2013). American Medical Society for Sports Medicine position statement: concussion in sport. Br.J.Sports Med. 47**,** 15-26.

Hawkins, R. D., Fuller, C. W., (1998). An examination of the frequency and severity of injuries and incidents at three levels of professional football. Br.J.Sports Med. 32, 326-332.

Hawkins, R. D., Fuller, C. W., (1999). A prospective epidemiological study of injuries in four English professional football clubs. Br.J.Sports Med. 33, 196-203.

Hawkins, R. D., Hulse, M. A., Wilkinson, C., Hodson, A., Gibson, M., (2001). The association football medical research programme: an audit of injuries in professional football. Br.J.Sports Med. 35, 43-47.

Heck, J. F., Clarke, K. S., Peterson, T. R., Torg, J. S., Weis, M. P., (2004). National Athletic Trainers' Association Position Statement: Head-Down Contact and Spearing in Tackle Football. J.Athl.Train. 39, 101-111.

Hölmich, P., Larsen, K., Krogsgaard, K., Gluud, C., (2010). Exercise program for prevention of groin pain in football players: a cluster-randomized trial. Scand.J.Med.Sci.Sports 20, 814-821.

Hoy, K., Lindblad, B. E., Terkelsen, C. J., Helleland, H. E., Terkelsen, C. J., (1992). European soccer injuries. A prospective epidemiologic and socioeconomic study. Am.J.Sports Med. 20, 318-322.

Inklaar, H., (1994a). Soccer injuries. I: Incidence and severity. Sports Med. 18, 55-73.

Inklaar, H., (1994b). Soccer injuries. II: Aetiology and prevention. Sports Med. 18, 81-93.

Inklaar, H., Bol, E., Schmikli, S. L., Mosterd, W. L., (1996). Injuries in male soccer players: team risk analysis. Int.J.Sports Med. 17, 229-234.

International Ice Hockey Federation, (2011). IIHF Injury Reporting System 2009-10. pp. IIHF Injury reporting system
2009-10.

Ivarsson, A., Johnson, U., Podlog, L., (2013). Psychological predictors of injury occurrence: a prospective investigation of professional Swedish soccer players. J.Sport Rehabil. 22, 19-26.

Johnson, U., Ivarsson, A., (2011). Psychological predictors of sport injuries among junior soccer players. Scand.J.Med.Sci.Sports 21, 129-136.

Junge, A., (2000). The influence of psychological factors on sports injuries. Review of the literature. Am.J.Sports Med. 28, S10-S15.

Junge, A., Dvorak, J., (2000). Influence of definition and data collection on the incidence of injuries in football. Am.J.Sports Med. 28, S40-S46.

Junge, A., Dvorak, J., Graf-Baumann, T., (2004a). Football injuries during the World Cup 2002. Am.J.Sports Med. 32, 23S-27S.

Junge, A., Dvorak, J., Graf-Baumann, T., Peterson, L., (2004b). Football injuries during FIFA tournaments and the Olympic Games, 1998-2001: development and implementation of an injury-reporting system. Am.J.Sports Med. 32, 80S-89S.

Junge, A., Dvorak, J., Rosch, D., Graf-Baumann, T., Chomiak, J., Peterson, L., (2000). Psychological and sport-specific characteristics of football players. Am.J.Sports Med. 28, S22-S28.

Junge, A., Engebretsen, L., Alonso, J. M., Renstrom, P., Mountjoy, M., Aubry, M., Dvorak, J., (2008). Injury surveillance in multi-sport events: the International Olympic Committee approach. Br.J.Sports Med. 42, 413-421.

Junge, A., Langevoort, G., Pipe, A., Peytavin, A., Wong, F., Mountjoy, M., Beltrami, G., Terrell, R., Holzgraefe, M., Charles, R., Dvorak, J., (2006). Injuries in team sport tournaments during the 2004 Olympic Games. Am.J.Sports Med. 34, 565-576.

Keller, C. S., Noyes, F. R., Buncher, C. R., (1987). The medical aspects of soccer injury epidemiology. Am.J.Sports Med. 15, 230-237.

Klugl, M., Shrier, I., McBain, K., Shultz, R., Meeuwisse, W. H., Garza, D., Matheson, G. O., (2010). The prevention of sport injury: an analysis of 12,000 published manuscripts. Clin.J.Sport Med. 20, 407-412.

Klunder, K. B., Rud, B., Hansen, J., (1980). Osteoarthritis of the hip and knee joint in retired football players. Acta Orthop.Scand. 51, 925-927.

Kofotolis, N. D., Kellis, E., Vlachopoulos, S. P., (2007). Ankle sprain injuries and risk factors in amateur soccer players during a 2-year period. Am.J.Sports Med. 35, 458-466.

Kristenson, K., Bjorneboe, J., Walden, M., Andersen, T. E., Ekstrand, J., Hagglund, M., (2013a). The Nordic Football Injury Audit: higher injury rates for professional football clubs with third-generation artificial turf at their home venue. Br.J.Sports Med. 47, 775-781.

Kristenson, K., Walden, M., Ekstrand, J., Hagglund, M., (2013b). Lower Injury Rates for Newcomers to Professional Soccer: A Prospective Cohort Study Over 9 Consecutive Seasons. Am.J.Sports Med.

Krosshaug, T., Andersen, T. E., Olsen, O. E., Myklebust, G., Bahr, R., (2005). Research approaches to describe the mechanisms of injuries in sport: limitations and possibilities. Br.J.Sports Med. 39, 330-339.

Langevoort, G., Myklebust, G., Dvorak, J., Junge, A., (2007). Handball injuries during major international tournaments. Scand.J.Med.Sci.Sports 17, 400-407.

Larsen, E., Jensen, P. K., Jensen, P. R., (1999). Long-term outcome of knee and ankle injuries in elite football. Scand.J.Med.Sci.Sports 9, 285-289.

Le, G. F., Carling, C., Reilly, T., (2008). Injuries in young elite female soccer players: an 8-season prospective study. Am.J.Sports Med. 36, 276-284.

Lindberg, H., Roos, H., Gardsell, P., (1993). Prevalence of coxarthrosis in former soccer players. 286 players compared with matched controls. Acta Orthop.Scand. 64, 165-167.

Matheson, G. O., Mohtadi, N. G., Safran, M., Meeuwisse, W. H., (2010). Sport injury prevention: time for an intervention? Clin.J.Sport Med. 20, 399-401.

Matser, E. J., Kessels, A. G., Lezak, M. D., Jordan, B. D., Troost, J., (1999). Neuropsychological impairment in amateur soccer players. JAMA 282, 971-973.

Matser, J. T., Kessels, A. G., Jordan, B. D., Lezak, M. D., Troost, J., (1998). Chronic traumatic brain injury in professional soccer players. Neurology 51, 791-796.

Matser, J. T., Kessels, A. G., Lezak, M. D., Troost, J., (2001). A dose-response relation of headers and concussions with cognitive impairment in professional soccer players. J.Clin.Exp.Neuropsychol. 23, 770-774.

Meeuwisse, W. H., (1991). Predictability of sports injuries. What is the epidemiological evidence? Sports Med. 12, 8-15.

Meeuwisse, W. H., (1994). Assessing causation of sport injury: a multifactorial model. Clin.J.Sport Med. 4, 166-170.

Meeuwisse, W. H., Love, E. J., (1998). Development, implementation, and validation of the Canadian Intercollegiate Sport Injury Registry. Clin.J.Sport Med. 8, 164-177.

Meeuwisse, W. H., Tyreman, H., Hagel, B., Emery, C., (2007). A dynamic model of etiology in sport injury: the recursive nature of risk and causation. Clin.J.Sport Med. 17, 215-219.

Mjolsnes, R., Arnason, A., Osthagen, T., Raastad, T., Bahr, R., (2004). A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. Scand.J.Med.Sci.Sports 14, 311-317.

Mohammadi, F., (2007). Comparison of 3 preventive methods to reduce the recurrence of ankle inversion sprains in male soccer players. Am.J.Sports Med. 35, 922-926.

Morgan, B. E., Oberlander, M. A., (2001). An examination of injuries in major league soccer. The inaugural season. Am.J.Sports Med. 29, 426-430.

Myklebust, G., Bahr, R., (2005). Return to play guidelines after anterior cruciate ligament surgery. Br.J.Sports Med. 39, 127-131.

Nielsen, A. B., Yde, J., (1989). Epidemiology and traumatology of injuries in soccer. Am.J.Sports Med. 17, 803-807.

Nigg, B. M., Yeadon, M. R., (1987). Biomechanical aspects of playing surfaces. J.Sports Sci. 5, 117-145.

Nilstad, A., Bahr, R., Andersen, T., (2012). Text messaging as a new method for injury registration in sports: A methodological study in elite female football. Scand.J.Med.Sci.Sports.

Øiestad, B. E., Engebretsen, L., Storheim, K., Risberg, M. A., (2009). Knee osteoarthritis after anterior cruciate ligament injury: a systematic review. Am.J.Sports Med. 37, 1434-1443.

Orchard, J. W., Newman, D., Stretch, R., Frost, W., Mansingh, A., Leipus, A., (2005). Methods for injury surveillance in international cricket. Br.J.Sports Med. 39, e22.

Orhant, E., Carling, C., Cox, A., (2010). A three-year prospective study of illness in professional soccer players. Res.Sports Med. 18, 199-204.

Ostenberg, A., Roos, H., (2000). Injury risk factors in female European football. A prospective study of 123 players during one season. Scand.J.Med.Sci.Sports 10, 279-285.

Parry, L., Drust, B., (2006). Is injury the major cause of elite soccer players being unavailable to train and play during the competitive season? Physical Thearpy in Sport 7, 58-64.

Pellman, E. J., Viano, D. C., Casson, I. R., Arfken, C., Powell, J., (2004). Concussion in professional football: injuries involving 7 or more days out--Part 5. Neurosurgery 55, 1100-1119.

Petersen, J., Thorborg, K., Nielsen, M. B., Budtz-Jorgensen, E., Holmich, P., (2011). Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. Am.J.Sports Med. 39, 2296-2303.

Peterson, L., Junge, A., Chomiak, J., Graf-Baumann, T., Dvorak, J., (2000). Incidence of football injuries and complaints in different age groups and skill-level groups. Am.J.Sports Med. 28, S51-S57.

Pilz, G. A., (2005). [Nurturing fair play in competitive sports. Results from a study on competitively oriented youth soccer]. Bundesgesundheitsblatt.Gesundheitsforschung.Gesundheitsschutz. 48, 881-890.

Poulsen, T. D., Freund, K. G., Madsen, F., Sandvej, K., (1991). Injuries in high-skilled and low-skilled soccer: a prospective study. Br.J.Sports Med. 25, 151-153.

Rahnama, N., Reilly, T., Lees, A., (2002). Injury risk associated with playing actions during competitive soccer. Br.J.Sports Med. 36, 354-359.

Roaas, A., Nilsson, S., (1979). Major injuries in Norwegian football. Br.J.Sports Med. 13, 3-5.

Roberts, W. O., Brust, J. D., Leonard, B., Hebert, B. J., (1996). Fair-play rules and injury reduction in ice hockey. Arch.Pediatr.Adolesc.Med. 150, 140-145.

Rogers, T. J., Alderman, B. L., Landers, D. M., (2003). Effects of life-event stress and hardiness on peripheral vision in a real-life stress situation. Behav.Med. 29, 21-26.

Roos, H., (1998). Are there long-term sequelae from soccer? Clin.Sports Med. 17, 819-31, viii.

Roos, H., Lindberg, H., Gardsell, P., Lohmander, L. S., Wingstrand, H., (1994). The prevalence of gonarthrosis and its relation to meniscectomy in former soccer players. Am.J.Sports Med. 22, 219-222.

Smith, R. E., Smoll, F. L., Ptacek, J. T., (1990). Conjunctive moderator variables in vulnerability and resiliency research: life stress, social support and coping skills, and adolescent sport injuries. J.Pers.Soc.Psychol. 58, 360-370.

Soligard, T., Bahr, R., Andersen, T. E., (2012). Injury risk on artificial turf and grass in youth tournament football. Scand.J.Med.Sci.Sports 22, 356-361.

Soligard, T., Grindem, H., Bahr, R., Andersen, T. E., (2010). Are skilled players at greater risk of injury in female youth football? Br.J.Sports Med. 44, 1118-1123.

Steffen, K., Andersen, T. E., Bahr, R., (2007). Risk of injury on artificial turf and natural grass in young female football players. Br.J.Sports Med. 41 Suppl 1, i33-i37.

Steffen, K., Pensgaard, A. M., Bahr, R., (2009). Self-reported psychological characteristics as risk factors for injuries in female youth football. Scand.J.Med.Sci.Sports 19, 442-451.

Straume-Naesheim, T. M., Andersen, T. E., Dvorak, J., Bahr, R., (2005). Effects of heading exposure and previous concussions on neuropsychological performance among Norwegian elite footballers. Br.J.Sports Med. 39 Suppl 1, i70-i77.

Straume-Naesheim, T. M., Andersen, T. E., IM, K. H., McIntosh, A. S., Dvorak, J., Bahr, R., (2009). Do minor head impacts in soccer cause concussive injury? A prospective case-control study. Neurosurgery 64, 719-725.

Surve, I., Schwellnus, M. P., Noakes, T., Lombard, C., (1994). A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the Sport-Stirrup orthosis. Am.J.Sports Med. 22, 601-606.

Tegnander, A., Olsen, O. E., Moholdt, T. T., Engebretsen, L., Bahr, R., (2008). Injuries in Norwegian female elite soccer: a prospective one-season cohort study. Knee.Surg.Sports Traumatol.Arthrosc. 16, 194-198.

Tropp, H., Askling, C., Gillquist, J., (1985). Prevention of ankle sprains. Am.J.Sports Med. 13, 259-262.

Turner, A. P., Barlow, J. H., Heathcote-Elliott, C., (2000). Long term health impact of playing professional football in the United Kingdom. Br.J.Sports Med. 34, 332-336.

Twellaar, M., Verstappen, F. T., Huson, A., (1996). Is prevention of sports injuries a realistic goal? A four-year prospective investigation of sports injuries among physical education students. Am.J.Sports Med. 24, 528-534.

van Mechelen, W., (1997). Sports injury surveillance systems. 'One size fits all'? Sports Med. 24, 164-168.

van Mechelen, W., Hlobil, H., Kemper, H. C., (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. Sports Med. 14, 82-99.

von Porat, A., Roos, E. M., Roos, H., (2004). High prevalence of osteoarthritis 14 years after an anterior cruciate ligament tear in male soccer players: a study of radiographic and patient relevant outcomes. Ann.Rheum.Dis. 63, 269-273.

Waldén, M., Hägglund, M., Ekstrand, J., (2005a). Injuries in Swedish elite football--a prospective study on injury definitions, risk for injury and injury pattern during 2001. Scand.J.Med.Sci.Sports 15, 118-125.

Waldén, M., Hägglund, M., Ekstrand, J., (2005b). UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. Br.J.Sports Med. 39, 542-546.

Waldén, M., Hägglund, M., Ekstrand, J., (2006). High risk of new knee injury in elite footballers with previous anterior cruciate ligament injury. Br.J.Sports Med. 40, 158-162.

Waldén, M., Hägglund, M., Ekstrand, J., (2007). Football injuries during European Championships 2004-2005. Knee.Surg.Sports Traumatol.Arthrosc. 15, 1155-1162.

Walden, M., Hagglund, M., Ekstrand, J., (2007). Football injuries during European Championships 2004-2005. Knee.Surg.Sports Traumatol.Arthrosc. 15**,** 1155-1162.

Waldén, M., Hägglund, M., Orchard, J., Kristenson, K., Ekstrand, J., (2011a). Regional differences in injury incidence in European professional football. Scand.J.Med.Sci.Sports.

Waldén, M., Hägglund, M., Werner, J., Ekstrand, J., (2011b). The epidemiology of anterior cruciate ligament injury in football (soccer): a review of the literature from a gender-related perspective. Knee.Surg.Sports Traumatol.Arthrosc. 19**,** 3-10.

White, P. E., Otago, L., Saunders, N., Romiti, M., Donaldson, A., Ullah, S., Finch, C. F., (2013). Ensuring implementation success: how should coach injury prevention education be improved if we want coaches to deliver safety programmes during training sessions? Br.J.Sports Med.

Woods, C., Hawkins, R., Hulse, M., Hodson, A., (2002). The Football Association Medical Research Programme: an audit of injuries in professional football-analysis of preseason injuries. Br.J.Sports Med. 36**,** 436-441.

Woods, C., Hawkins, R., Hulse, M., Hodson, A., (2003). The Football Association Medical Research Programme: an audit of injuries in professional football: an analysis of ankle sprains. Br.J.Sports Med. 37**,** 233-238.

Woods, C., Hawkins, R. D., Maltby, S., Hulse, M., Thomas, A., Hodson, A., (2004). The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries. Br.J.Sports Med. 38**,** 36-41.

Papers I-V

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